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The alteration of pyrochlore to columbite in carbonatites in Tanganyika.[1]

(With Plates XX and XXI.)

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Summary. The formation of columbite has been observed in two carbonatites in south-west Tanganyika where it is due to autometasomatism following the emplacement of the bodies. Disoriented aggregates of columbite crystallites are formed as pseudomorphs after cubo-octahedra of pyrochlore in sövite. This alteration is accompanied by the addition of Fe, conversion of amphibole and biotite in the sövite to a ferruginous talc, the formation of an iron-bearing carbonate, and the introduction of colloform silica; Ca and Na are lost in part. The general alteration of the sövite can be ascribed to the influx of iron-bearing solutions at relatively low temperature and high pressure.

COLUMBITE is not a primary mineral in carbonatites, except perhaps at Fen (Sörum, 1956), and in each of its occurrences in Tanganyika it has been formed by the replacement of pyrochlore as part of the general alteration of the host rock. So far it has been found in only the Mbeya (Fawley and James, 1955) and Ngualla[2] carbonatites which are situated in south-west Tanganyika; pyrochlore from carbonatites in the coastal and northern volcanic provinces does not exhibit such alteration.

The Mbeya carbonatite lies in the floor of the southern end of the Rukwa trough (a rift valley) and is possibly Jurassic in age; it is thought

[1] Published by permission of the Director, Geological Survey of Tanganyika.

[2] Described by T. C. James in unpublished reports of the Geological Survey of Tanganyika, 1954.

to be in the core of an eroded volcano. The Ngualla carbonatite is about eighty miles to the north-west of the Mbeya carbonatite and about twenty miles to the east of the Rukwa trough. It is principally sövite with minor amounts of rauhaugite, and is a circular body some two miles in diameter within a rim of fenitized brecciated quartz-porphyry. Its age is apparently older than late Cretaceous and may be similar to that of the Mbeya carbonatite.

Detailed descriptions of these carbonatites have not been published and it would seem desirable to outline their petrography before giving an account of the alteration of pyrochlore and some associated reactions, and, finally, considering the significance of these late-stage effects.

In the Mbeya carbonatite the alteration of pyrochlore to columbite is confined to certain bands of altered sövite within the body. The alteration of the sövite is shown by the formation of large porphyroblasts of what was probably a ferruginous carbonate, which has been subsequently converted either by weathering or low-grade autometamorphic effects to hematite, limonite, and quartz. Alteration is also shown by the development of secondary quartz, often in colloform masses, in the carbonates forming the matrix of the rock. In such rocks rims of columbite are developed by replacement around the pyrochlore crystals and large cracked crystals are infiltrated by veins of columbite. Fluorite is developed in and around the altered crystals.

One specimen of sövite from near the centre of the Ngualla carbonatite contains disoriented aggregates of columbite pseudomorphous after pyrochlore crystals. In other aspects the rock appears to be a normal sövite, but there is some alteration in the other members of the accessory mineral assemblage.

Museum zone, Mbeya carbonatite.

The apatite–sövite forming the Museum zone is unaltered and is regarded as typical of the carbonatite (Fawley and James, 1955). It is a medium-grained (1 to 2 mm.) equigranular aggregate, shown by partial chemical analysis to be composed of 71 % calcite, 17 % dolomite, and 12 % of accessory minerals of which apatite amounts to about 10 % and the remaining 2 % represents amphibole, biotite, quartz, pyrochlore, magnetite, and pyrite. Modal analysis of thin sections stained with Alizarin Red S (Mitchell, 1956) shows dolomite to be less abundant than the chemical analysis indicates, suggesting that the calcite may be magnesian. Magnesian calcite has been recorded from Fen by Goldsmith *et al.* (1955). Calcite grains locally contain a dust of minute hema-

tite inclusions, whereas dolomite is always clear. Dolomite appears to have crystallized after calcite and is concentrated around bands of the accessory mineral assemblage. Apatite in rounded grains (up to 0·5 mm.) forms schlieren of granular aggregates and occasional single grains scattered throughout the rock.

The accessory minerals are all euhedral, although amphibole and biotite are more or less carbonated and pyrochlore is corroded and embayed by carbonates. A relatively abundant accessory mineral is an *alkali-amphibole*, with $2V_\alpha$ about 70°, $\gamma \wedge c$ 25°, γ 1·625, β 1·612 and an alkali content of 5·31 % Na_2O and 2·29 % K_2O. Some crystals are up to 2 mm. in length and 1 mm. in width, but most are smaller and rather fibrous. They cut directly across the matrix of granular calcite and across the bands of granular apatite. Carbonation is often intense and in large crystals starts along the cleavages. Small crystals within the carbonates are usually completely replaced, only ghosts of the crystal outlines remaining. The amphibole and its carbonated relics tend to occur in bands, and where alteration is intense the surrounding carbonate is clear dolomite. Campbell Smith (1953) does not mention the occurrence of any amphibole in the sövites of the Chilwa Series; neither did von Eckermann (1948) find any in the Alnö sövites, but his description of the carbonation of sodic pyroxene in the Smedsgården dyke is reminiscent of the alteration of alkali-amphibole in the Mbeya carbonatite. At Iron Hill, however, potash-rich amphiboles with optics resembling tremolite are abundant in the carbonate rocks; they are composed principally of the soda-tremolite, ferri-glaucophane, and hastingsite end-members (Larsen, 1942). An amphibole of similar composition and optics has recently been described from the type sövite of Söve, Fen, by Sæther (1957). Riebeckite and crocidolite on the other hand occur as late cross-fibre veins in many carbonatites.

A constant accessory is *biotite* with $2V_\alpha$ 13°, γ 1·609, reversed pleochroism α deep orange-red, β, γ pale orange-red, and an X-ray powder diffraction pattern corresponding to the 1M or 3T polymorph of Smith and Yoder (1956); crystals are elongated parallel to *c*, are zoned with more intensely coloured rims, and are more or less replaced by carbonate along the cleavages and marginally. Phlogopite with similar pleochroism has been described without chemical analysis from Alnö, Fen, Iron Hill, and Mountain Pass; von Eckermann (1948, p. 69) points out that the material from Alnö is low in Mn and is not manganophyllite as Högbom had suggested.

Pyrochlore is yellowish to reddish-brown, often concentrically zoned,

and slightly anisotropic in thin-section. Small crystals and the inner zones of large crystals exhibit only {111} faces, whereas large crystals tend to develop {100} faces as well in the later stages of their growth (pl. XX, figs. 10, 12) and examples are known of the development of {011} faces on the octahedra (pl. XX, fig. 13). A not uncommon habit is produced by the preferential development of a diametrically opposed pair of octahedral faces to give a tabular crystal (pl. XX, fig. 11). Inclusions of euhedral apatite are common at the margins of large crystals; crystal outlines usually transgress the zoning, indicating corrosion after the completion of crystallization as euhedral crystals; and embayment by calcite is common. Size varies from 5 mm. to 0·1 mm. between cube faces. The specific gravity of fresh material is 4·43. The unit-cell edge is a 10·405 Å. for brown pyrochlore from the Museum zone and 10·428 Å. from the rather similar Mstari zone.

Quartz occurs as small grains, interstitially and in secondary veinlets. Magnetite occurs in octahedra and pyrite in cubes, both occasionally corroded. The alteration and corrosion of the euhedral minerals of the accessory mineral assemblage suggest that they were not in equilibrium with the crystallizing carbonates and may be to some extent xenocrystic.

Chini zone, Mbeya carbonatite.

Altered sövite containing pyrochlore altered to columbite is found at the north-east end of the Chini zone (Fawley and James, 1955). The rock is a fine-grained sövite composed mainly of calcite with prominent bands of granular (up to 1 mm.) apatite, large crystals of altered pyrochlore, large pseudomorphs of quartz and platy limonite after a carbonate that was probably chalybite, and occasional disseminated grains of apatite. The rock has undergone extensive changes, but its original composition may have been similar to that of the Museum zone sövite. The large pseudomorphs after chalybite are absent from the Museum zone sövite and are considered to be the product of an iron metasomatism affecting the Chini zone. The accessory mineral assemblage has undergone considerable alteration: amphibole and biotite are extensively carbonated; much more quartz, some of it obviously secondary, is present; pyrochlore is cloudy and opaque around its edges and along cracks, and in this partially altered material have grown disoriented crystallites of columbite, in many instances coalescing into massive columbite, which completely replaces the pyrochlore; magnetite and pyrite do not appear and have presumably been altered to the hematite and limonite that are common in the partly weathered specimens used for this description.

Staining tests show that the large equigranular crystals of carbonate forming the bulk of the rock are calcite although a partial chemical analysis of the rock indicates 5 % dolomite and 73 % calcite. Small inclusions of dolomite occur in many of the calcite grains and are oriented parallel to the calcite cleavage (pl. XXI, fig. 5). Some of the inclusions are limonite, which may be interpreted either as original inclusions of limonite in the calcite crystals or as due to the subsequent alteration of a ferruginous dolomite or ankerite. Large pseudomorphs composed of platy limonite and quartz, up to 1 cm. in size, are apparently after chalybite; a box-work of limonite follows the {100} cleavage directions and the intervening carbonate has been replaced by quartz (pl. XXI, fig. 6). In weathered specimens increased development of limonite obscures the box-work.

Amphibole is unaltered only where it occurs in bands of apatite. It has not been analysed, but appears to be similar to the alkali-amphibole of the Museum zone. A number of linear zones of fine-grained carbonate in the matrix of the rock may represent altered amphibole. The reddish *biotite* is partly carbonated and one large euhedral crystal can be seen to have recrystallized in minute disoriented flakes.

Pyrochlore occurs in crystals up to 1 cm. in size, usually zoned and with little sign of embayment by carbonates. Alteration to columbite is preceded by a change in the pyrochlore, which becomes cloudy and opaque (pl. XXI, figs. 1, 3); an X-ray powder photograph of this material shows that it is still pyrochlore, possibly with some amorphous material, and that the unit cell edge a 10·405 Å. remains constant. It is evident that pyrochlore in carbonatites is easily attacked by carbonate solutions and it is often embayed and veined by calcite. In the example shown in pl. XXI, fig. 2, calcite is replacing partially altered pyrochlore along its junction with columbite veins.

Columbite (pl. XX, figs. 7, 8, 9) replaces pyrochlore around its edges and along cracks in the larger crystals. Both the development of the opaque phase in the pyrochlore and the growth of columbite are shown in pl. XX, fig. 14, and pl. XXI, figs. 1, 2, and 3. The opaque phase is always developed in pyrochlore before alteration to columbite but in many cases only small individual grains of columbite are developed within it. The growth of columbite around the edges of the pyrochlore crystals is usually not uniform, massive aggregates being developed only at a few points. Occasionally the zoning of the pyrochlore is reproduced in the pseudomorphous columbite aggregates in which definite bands parallel to and replacing zones in the pyrochlore can be seen. Within the

pyrochlore crystals the veins of columbite are generally massive aggregates. An unusual variation is shown in pl. XXI, fig. 2, where carbonate is interposed between the columbite veins and the opaque phase of the pyrochlore. Often fluorite is developed within or adjacent to the columbite pseudomorphs.

Ngualla carbonatite.

Columbite pseudomorphs after pyrochlore are found in apparently unaltered sövite from near the centre of the Ngualla carbonatite. The sövite is composed of equigranular calcite, scattered grains of dolomite containing oriented rhombs of calcite (the inverse of the intergrowth observed in the Chini zone), granular apatite associated with amphibole and talc in schlieren, grains of apatite disseminated throughout the rock, and an accessory mineral assemblage of amphibole, talc, biotite, columbite, and occasional pyrite and magnetite. The rock shows little sign of alteration although some has presumably taken place since the amphibole is altered to a disoriented aggregate of talc, biotite is altered to talc, and disoriented aggregates of columbite have completely replaced cubo-octahedral crystals of pyrochlore. The *amphibole* of the columbite-bearing sövite appears to be similar to that of the Museum and Chini zones of the Mbeya carbonatite. A coarse-grained calcite-rich sövite contains a deep green alkali-amphibole (up to 10 mm.) with 5·90 % Na_2O and 2·18 % K_2O.

Both amphibole and biotite alter to a pleochroic green mineral which was identified by its X-ray powder pattern as *talc*. Alteration has in both cases often gone to completion, to produce pseudomorphs composed of a disoriented aggregate of minute flakes of talc. Occasional flakes are dispersed among the carbonates. The talc is unusual in having moderately strong pleochroism with α colourless, β, γ olive-green; its refractive index is rather high, γ 1·605, and $2V_\alpha < 10°$. These optical properties are associated with the remarkably high iron content of 6·76 %total iron (calculated as FeO). Talc does not normally contain more than 2·5 % FeO, and then according to Gruner (1944) there is a gap in the Fe–Mg replacement series until minnesotaite is reached, with 33·66 % FeO and 6·26 % MgO. No member of the talc-minnesotaite series has hitherto been recorded in a sövite.

A red *biotite* is common in the Ngualla sövites. It has $2V_\alpha < 10°$, γ 1·638, and a pleochroic scheme, α foxy-red, β, γ colourless; its X-ray powder pattern is consistent with either the 1M or 3T polymorph. Crystals are elongated in the *c* direction and the pleochroism is blotchy.

Alteration to talc is extensive and may develop at various points within the crystals, invariably forming a wide rim around their edges (pl. XXI, fig. 4); the talc is interleaved with and feathers out into the biotite it is replacing. Magnetite occurs in grains elongated parallel to the cleavage of the talc, and where it is adjacent to calcite, talc is rimmed with limonite, probably a product of secondary alteration.

Unaltered *pyrochlore* has only been found in a magnetite segregation in the sövite. It occurs in pale yellow transparent octahedra and cubo-octahedra, less than 0·5 mm. in size, and with a 10·425 Å.

Pseudomorphs of *columbite* after pyrochlore have been extracted from the rock by treatment with dilute hydrochloric acid. The original habit of the pyrochlore was clearly octahedral modified by {100} faces (pl. XX, figs. 4, 5, 6), the characteristic habit of pyrochlore in the Mbeya carbonatite and in sövites in general. The columbite is black in colour, metallic in lustre, and completely replaces the pyrochlore. Its X-ray rotation pattern shows that it is an aggregate of disoriented crystallites (pl. XX, fig. 3). A partial chemical analysis[1] of the columbite shows the presence of 2 % MnO, 19 % FeO (total iron), 67 % Nb_2O_5, and 3 % TiO_2.

The alteration of pyrochlore to columbite.

In the Mbeya carbonatite the alteration of pyrochlore to columbite can be traced through various stages (pl. XX, fig. 14; pl. XXI, figs. 1, 3). The pyrochlore crystals are zoned and, although the edges may be partially embayed by carbonates, the general outline of the crystals is euhedral. Columbite replaces pyrochlore along the crystal margins and anastomozing veins, which tend to be parallel to the poor octahedral cleavage. The first stage of alteration is the development in the pyrochlore crystals, usually along the margins, of a white opaque material containing a few minute black grains. The X-ray powder pattern of this material shows that it is still essentially pyrochlore although the diffuse lines suggest incipient breakdown of the pyrochlore structure. Continued alteration gives rise to the growth of small grains of columbite in this cortex, which may eventually coalesce to form a columbite rim. A single crystal rotation photograph (pl. XX, fig. 2) of a portion of the rim attached to residual pyrochlore shows the normal pyrochlore pattern of discrete reflections with a superimposed 'powder' pattern of θ-curves corresponding to columbite; the columbite is therefore present as a disoriented aggregate of minute grains. It was necessary to heat this material at 450° C. in nitrogen for two hours to produce a sharp columbite

[1] Analyst: T. D. Rees, formerly Geochemist, Geological Survey of Tanganyika.

pattern. In fact before heat treatment the columbite pattern was too diffuse to be recognizable.

At Ngualla pyrochlore is completely replaced by columbite; the intermediate stages in the process of alteration are not seen and the original presence of pyrochlore is inferred from the cubo-octahedral shape of the pseudomorphs. Unaltered pyrochlore has, however, been found in another part of the carbonatite. A single-crystal rotation photograph of one of these pseudomorphs rotated about a [111] axis shows a pattern of θ-curves of columbite that is quite sharp even in unheated material.

The rotation photographs, pl. XX, figs. 2 and 3, show that the columbite crystallites in the pseudomorphs are completely disoriented and quite small.

In general, pseudomorphous minerals can occur in three types of aggregation:

A completely disoriented aggregate or 'powder', of microscopic or submicroscopic crystallites. Examples are common and occur even where there is some structural similarity between the pseudomorphous mineral and its host, if the transformation requires the breaking of bonds in such a way that those parts of the structure that persist have some choice of orientation in the new structure.

A microscopic or submicroscopic aggregate of crystallites completely or partially oriented with respect to the morphological symmetry, and therefore to the lattice, of the replaced mineral. Epitaxic replacement as defined by Kostov (1956) produces this type of pseudomorph. In the transformation bonds are broken in such a way that units of the structure persist continuously in at least one direction, as for instance in the linking of pyroxene chains to form double amphibole chains in the homoaxial intergrowths of tremolite in diopside.

A single crystal, twinned or untwinned, with the morphology of the replaced mineral. Examples occur among the products of polymorphic inversions, but are rare where a change in composition is involved in the pseudomorphing process.

The chemical similarity between pyrochlore, essentially $(Ca,Na)_2Nb_2O_6(O,OH,F)$, and columbite, $(Fe,Mn)Nb_2O_6$, might suggest the likelihood of some degree of orientation in the columbite crystallites of the pseudomorphs. A consideration, however, of the structural changes involved in the pseudomorphing process shows why complete disorientation is observed.

An important factor in the replacement of pyrochlore by columbite is

the reduction in size of the ions in the *A* position, when Fe^{2+} and Mn^{2+} replace Ca^{2+} and Na^{+}. The latter are in eightfold coordination in pyrochlore (Rosén and Westgren, 1938), and their replacement by the smaller Fe^{2+} and Mn^{2+} ions, which can only coordinate six oxygen atoms, results in collapse of the Nb–O framework of pyrochlore to produce the less symmetrical Nb–O framework of columbite. This collapse involves breaking of strong Nb–O, largely covalent, bonds and complete disruption of the structure. The rearrangement can only be propagated over short distances before the distortion of the Nb–O framework becomes too great and a new sequence of adjustments must be begun, that is, a new columbite crystallite. The size of the columbite crystallites has not been determined, but the absence of spottiness on the θ-lines of the rotation photographs of the Ngualla pseudomorphs (pl. XX, fig. 3) indicates an average diameter of less than 10^{-4} cm. The inability of the pseudomorphs from the Mbeya carbonatite to give a sharp pattern without previous heat treatment (pl. XX, fig. 2) indicates rather shorter-range order.

The significance of the alteration of pyrochlore to columbite.

The changes accompanying the alteration of pyrochlore to columbite differ considerably in the Mbeya and Ngualla carbonatites. In the Mbeya carbonatite it appears that large crystals of an iron-bearing carbonate probably crystallized during the formation of the columbite. Limonite and hematite were produced by the subsequent exsolution and decomposition of the carbonate, and by alteration of magnetite and pyrite. Some quartz has been introduced into the sövite. The iron content of such sövites in the Chini zone (2·7 % Fe_2O_3) considerably exceeds that of the Museum zone sövite (1·1 % Fe_2O_3).

At Ngualla the columbite occurs in an apparently unaltered sövite. However, a high proportion of the original alkali-amphibole is completely converted to ferruginous talc. Biotite is also altered both around its margins and at centres within the crystals to ferruginous talc and magnetite. There is no evidence of appreciable quantities of iron in the carbonate minerals nor is there any limonite in the rock. It is believed that the alteration of amphibole and biotite took place at the same time as the alteration of pyrochlore to columbite. All the processes involve the introduction of iron into the rock but in rather smaller amount than in the Chini zone of the Mbeya carbonatite.

The alteration of pyrochlore to columbite involves only the addition of iron, or iron and manganese, and the removal of calcium, alkalis, and

fluorine. The niobium content of both minerals is similar and the high niobium to tantalum ratio characteristic of pyrochlore in carbonatites is inherited in the columbite. In the Mbeya carbonatite many of the partially altered pyrochlore crystals have a core containing purple fluorite. It seems reasonable to suppose that the fluorite is a by-product of the alteration, both calcium and fluorine being expelled from pyrochlore during the formation of columbite.

The alteration of amphibole and biotite to talc at Ngualla provides a clue to the physico-chemical conditions operative during the pseudomorphous alteration of pyrochlore to columbite. However, there is little exact information about the stability field of talc in the presence of calcite and, moreover, data relating to the composition $Mg_3Si_4O_{10}(OH)_2$ will be somewhat modified by the high iron content of the Ngualla talc, although such modification is likely to be well within the limits of precision of the data available. The lowest temperature at which talc can form is controversial. It has been reported as a weathering product, but the lowest well-authenticated temperature for natural talc formation is apparently of the order of 100° C. for authigenic growth in the Permian evaporites of Eskdale, Yorkshire (Stewart, 1949), under conditions of considerable hydrostatic pressure. The upper temperature limit of talc formation in the presence of an adequate supply of calcium appears to lie near the top of the greenschist facies (Turner and Verhoogen, 1951) or in the lower grades of the albite–epidote–amphibolite facies (Ramberg, 1952); thus the upper limit is of the order of 200° C. to 300° C. at pressures of about 2000 bars (Rosenqvist, 1952). Such conditions are consistent with what may be expected in a volcanic neck after active volcanism has ceased and before erosion has removed the overlying pile. In the Mbeya carbonatite talc formation has not been observed and the alteration of the sövite amounts to the formation of an iron-bearing carbonate and the introduction of colloform quartz. In this case the physico-chemical conditions cannot be estimated; the sövites exposed at surface lie near the base of the original volcanic pile. The alteration processes both at Ngualla and Mbeya may be regarded as autometasomatic.

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EXPLANATION OF PLATE XX.

FIG. 1. X-ray powder pattern of pyrochlore from Museum zone, Mbeya carbonatite, taken with Cu-$K\alpha$ radiation in a 6 cm. diameter camera.

FIG. 2. X-ray rotation pattern of a fragment of pyrochlore partly altered to columbite, from Chini zone, Mbeya carbonatite, taken with Cu-$K\alpha$ radiation in a 6 cm. diameter camera. The discrete reflections are due to pyrochlore. The powder lines are due to a completely disoriented aggregate of crystallites of columbite to which the pyrochlore is altering.

FIG. 3. X-ray pattern produced by a pseudomorph of columbite after pyrochlore, from Ngualla carbonatite, rotated about a [111] axis, radiation Cu-$K\alpha$, camera diameter 6 cm.

FIGS. 4–6. Cubo-octahedral pseudomorphs of columbite after pyrochlore from Ngualla. Fig. 4 shows a tabular crystal formed by the preferential development of a pair of opposed {111} faces. Magnification $\times 4$.

FIGS. 7–9. Cubo-octahedral pseudomorphs of columbite after pyrochlore from Chini zone, Mbeya carbonatite. Figs. 7 and 9 show tabular crystals. In the crystals shown in figs. 7 and 8 pits produced by the solution of apatite crystals are visible. Magnification $\times 2$.

FIGS. 10–13. Pyrochlore crystals from Museum zone, Mbeya carbonatite. Fig. 10 shows the forms {111} and {100} in equal development. Fig. 11 shows a tabular crystal exhibiting the forms {111} and {100} with preferential development of a pair of opposing {111} faces; the crystal is shown in the same orientation as that in fig. 10. Fig. 12 shows the common habit of pyrochlore in the Mbeya carbonatite. Fig. 13 shows the forms {111} and {011}—a rare habit of pyrochlore in the Mbeya carbonatite. Magnification $\times 2$.

FIG. 14. Thin-section showing the alteration of zoned pyrochlore (transparent) to columbite (opaque), from the Mbeya carbonatite. The prismatic crystals on the right-hand side are apatite. Columbite forms a rim to the crystal and anastomozing veins in the body of the crystal tend to follow {111} cleavage directions. Magnification $\times 14$.

Explanation of Plate XXI.

Fig. 1. Polished section illuminated by inclined light showing the development of columbite around the margin of a pyrochlore crystal and the coalescence of columbite veins in the interior. Bordering the columbite veins is a white incipient alteration product of pyrochlore. Chini zone, Mbeya carbonatite. Magnification ×16.

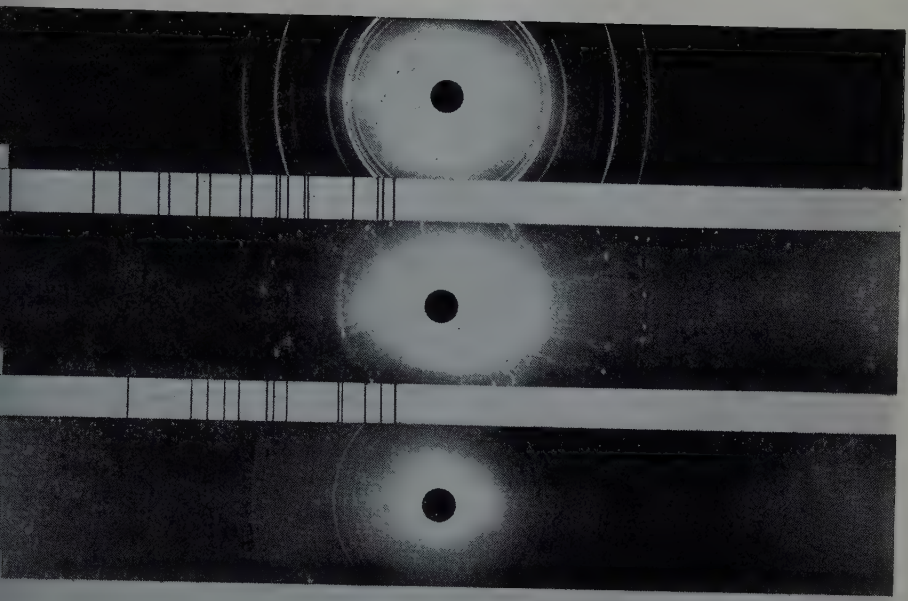
Fig. 2. Thin-section showing the development of a carbonate at the junction of columbite veins and unaltered pyrochlore, replacing the white alteration product. Chini zone, Mbeya carbonatite. Magnification ×16.

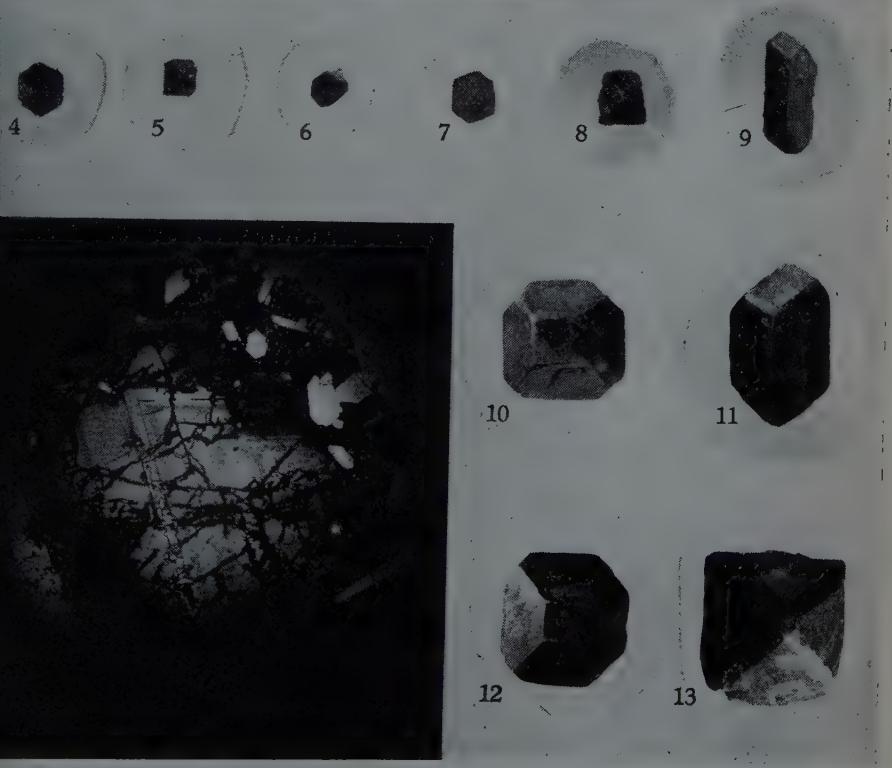
Fig. 3. Thin-section illuminated by inclined light showing the extensive development of the white alteration product of pyrochlore and marginal development of columbite. Chini zone, Mbeya carbonatite. Magnification ×32.

Fig. 4. Thin-section showing the marginal alteration of biotite to ferruginous talc. Blotchy pleochroism can be seen in both of the large crystals of biotite. The matrix of the rock is calcite. Apatite needles are visible in the top right-hand corner. Ngualla carbonatite. Magnification ×14.

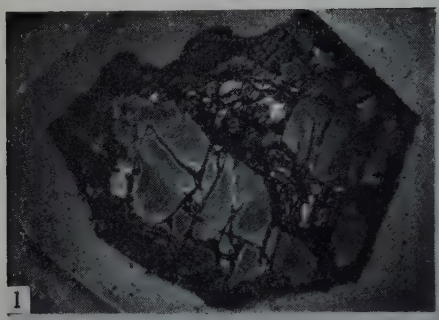
Fig. 5. Thin-section of calcite with oriented rhombs of dolomite. The calcite is stained with Alizarin Red S. Chini zone, Mbeya carbonatite. Magnification ×200.

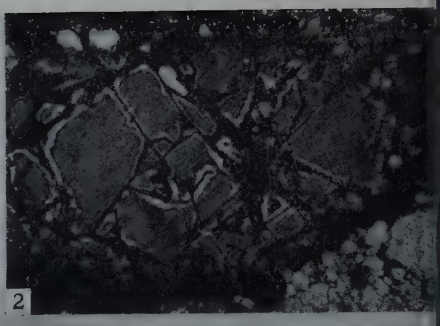
Fig. 6. Thin-section of a box-work of limonite in secondary quartz after a ferruginous carbonate. Chini zone, Mbeya carbonatite. Magnification ×100.

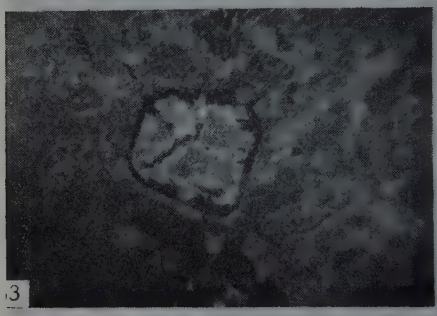


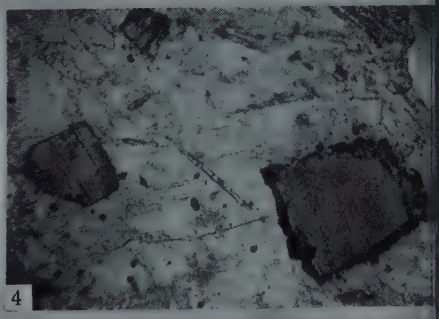


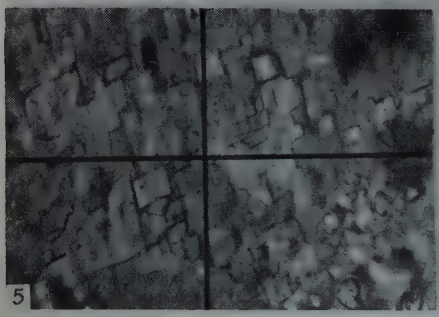
T. C. James and Duncan McKie: Pseudomorphs of columbite after pyrochlore

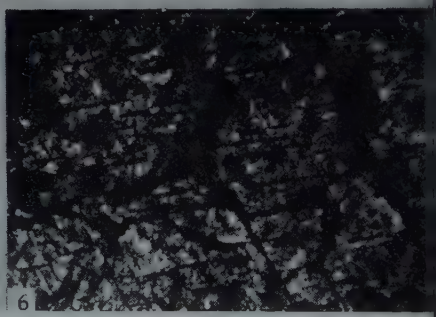












T. C. JAMES AND DUNCAN MCKIE: PSEUDOMORPHS OF COLUMBITE AFTER PYROCHLORE

New data for dumortierite.

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[Read 27 March 1952.]

Summary. New chemical, optical, and X-ray data have been obtained for dumortierite. The unit cell, space group *Pcmn*, contains $4[(Al,Fe)_7BSi_3O_{18}]$. Brown gem quality material from Ceylon has α 1·6860, black, = [001], β 1·722, deep red-brown, and γ 1·7229, brown, with $2V_\alpha$ 13°, $r > v$. X-ray powder data are given.

A NATIVE-CUT, dark red-brown, transparent gemstone weighing 0·369 g. bought in Ceylon by Kenneth Parkinson in 1950 was submitted to us in 1951 for determination after measurements of its physical properties (see below) had failed to provide an identification. An X-ray powder photograph of material scraped with a diamond from the girdle of the stone proved it to be dumortierite; the photograph was practically identical with one of a purple dumortierite from San Diego Co., California (B.M. 1905,6), and in reasonable agreement with the data of N. L. Bowen and R. W. G. Wyckoff (1926). As the stone was a single crystal it was ideally suitable material for the determination of the unit-cell dimensions of the mineral, which had not previously been obtained, probably because it is rarely found in this condition: most apparently single crystals consist of parallel aggregates of intimately twinned needles. Mr. B. W. Anderson, who had purchased the stone and submitted it to us for identification, readily agreed to have it recut so as to provide material for the X-ray study and for chemical analysis.

Rotation and powder X-ray photographs gave the cell-dimensions: a 11·79±0·01, b 20·209±0·002, c 4·7015±0·001 Å., and axial ratios $a:b:c = 0{\cdot}5834:1:0{\cdot}2326$. Systematic diffraction absences indicate the space-group *Pcmn* (D_{2h}^{16}), assuming holohedral symmetry; they are: $hk0$ only observed for $(h+k)$ even, $0kl$ only for l even.

Dumortierite crystals are usually very poorly developed and multiply twinned on m {110}, giving aragonite-like sixlings (E. Bertrand, 1880); the only goniometric data in the literature are: J. S. Diller (1881) observed the prism m {110} and cleavage plane a {100}, with am 28° (30° 16′ calc. from the X-ray data). G. Linck (1899) observed a prism of

69° 6′ angle, probably {250} (calc. (250):($\bar{2}$50) 68° 52′). And W. T. Schaller (1905) studied crystals from Clip, Arizona, and from Harlem, New York, which gave rather poor reflections; he deduced axial ratios $a:b:c = 0{\cdot}8897:1:0{\cdot}6871$, and indexed his observed forms *a* {100}, *b* {010}, *l* {120}, *g* {320}, more rarely *m* {110} and *n* {210}, and very rarely (once each) *d* {102} and *v* {203}; referred to the X-ray unit cell Schaller's results give remarkably good agreement considering the nature of his material: transformation, Schaller to X-ray, [200/030/001], $a:b:c = 0{\cdot}5931:1:0{\cdot}2290$, *a* {100}, *b* {010}, *l* {310}, *g* {110}, *m* {230}, *n* {430}, *d* {101}, *v* {403}.

Few chemical analyses of dumortierite have been made, and several of these are imperfect or were made on material of doubtful purity. Spectrographic examination of our material showed that apart from the principal elements Si, Al, Fe, and B there were only traces of Ti and Sn. Similar results, except that the trace elements detected were Mn, Ti, Mg, and Cu, were also obtained for three other specimens of dumortierite: B.M. 67299 from Clip, Yuma Co., Arizona; B.M. 81006 from California;[1] B.M. 1905,6 from San Diego Co., California; and B.M. 1925,612 from Ashby, Addington Co., Ontario. The fragments of gem material available (B.M. 1953,76) weighed 34 mg.; analysis, on 9 mg., gave the data included in table I (the low total is due to a slight leak in the crucible used for the sodium carbonate fusion, and should not affect the ratios of the oxides). The state of oxidation of the iron was not determined because of the small amount of material available.

With the observed cell-dimensions and density, and neglecting the water as an impurity, probably adsorbed on the powder prepared for analysis, the empirical unit cell contents included in table I are calculated; they show a reasonably close approximation to $4[(Al,Fe)_7BSi_3O_{18}]$, which with Al:Fe = 20:1 and the observed cell-dimensions would require the percentage composition and density given under 'calc.' in table I.

Following W. E. Ford (1902) we have rejected those analyses in the literature that show no boron[2] or that show appreciable alkalis (A. Damour, 1881; R. B. Riggs, 1887; P. Jannasch in J. Romberg, 1893; W. Schimpff in G. Linck, 1899; H. A. Weber, 1900). There remain

[1] Purchased in 1896, and therefore probably from Dehesa, San Diego Co.

[2] These include the only analysis yet made of material from the original locality, Beaunan, vallée de l'Iseron, Rhône, France; if the boron is assumed to be mainly included with the Al_2O_3 (cf. Min. Mag., 1941, vol. 26, p. 128), this analysis falls in line with the rest.

TABLE I. Chemical composition, optical properties, and empirical unit-cell contents of brown gem dumortierite, B.M. 1953,76, from Ceylon; together with the calculated composition and density for the idealized formula $4[(Al,Fe)_7BSi_3O_{18}]$ with Al:Fe = 20:1. Optical data, density, and hardness by B. W. Anderson.

	Obs.	Calc.			
SiO_2	32·7	31·00	Si	12·9	α 1·6860, black, = [001]
Al_2O_3	55·5	58·44	Al	25·7	β 1·722, deep red-brown
Fe_2O_3	4·4	4·58	Fe	1·3	γ 1·7229, brown
B_2O_3	4·9	5·98	B	3·3	$2V_\alpha$ 13°, $r > v$
H_2O	0·4	—	O	71·2	
Total	97·9	100·00			
$D_{4^\circ}^{20^\circ}$	3·41 ±0·02	3·450	(Si+Al+Fe+B)	43·2	Twinned, composition plane ‖ [001], optic axial planes of twin-members are at 58° obs. (60° 32′ calc. from X-ray cell dimensions). Hardness 8½.

eleven analyses, which have been recalculated to a basis of 72 oxygen atoms (excluding H_2O) and are compared with our new analysis in table II; it will be seen that they agree well with the formula $4[(Al,Fe)_7BSi_3O_{18}]$. Unfortunately few of the analyses are directly linked with full optical data. Water has often been regarded as an essential constituent of dumortierite, but the 0·4 % found in the gem material would only correspond to 1·0 (OH) per unit cell, and the minimum number of equivalent positions in space-group *Pcmn* is 4; we conclude that the appreciable amounts of water shown in several analyses are either adsorbed on the very finely fibrous material or due to incipient alteration, though the possibility of isomorphous replacement, perhaps of the type $R''OH \rightleftharpoons AlO$, cannot be excluded.

W. T. Schaller (1905) assumed that the titanium of anal. 5 was present as Ti_2O_3 and the iron as Fe_2O_3, both replacing Al_2O_3, and this assumption was followed by T. L. Walker in presenting anal. 8 and by S. K. Chatterjee in anal. 11; the mineral is practically insoluble in acids, including hydrofluoric, and it is clear that there was no experimental evidence for the assumption. In anal. 10 by F. Raoult, the titanium is again reported as Ti_2O_3; neither Raoult nor Losert (anal. 9) states how the state of oxidation of the mineral was determined, and without knowing the method used it is impossible to assess the probable accuracy of this difficult determination. Fortunately the amounts of Fe and Ti are small, so that the uncertainty as to their state of oxidation does not appreciably affect the atomic ratios calculated on a basis of 72 oxygen atoms.

The only refractive index data for analysed material are for anals. 8, 9, 11, and 12, and are not adequate to draw any definite conclusions about

TABLE II. Chemical data for dumortierite recalculated to a basis of 72 oxygen atoms. Analyses showing no boron and analyses showing appreciable alkalis have been omitted. Total iron as Fe''' except in anals. 9 and 10; Ti as Ti^{iv}.

	1.	2.	3.	4.	5.	6.	7.	7a.	8.	9.	10.	11.	12.	13.
Si	12·37	11·00	11·56	11·83	11·13	12·04	11·28	11·22	11·86	12·89	11·84	11·50	13·0	12
Al	29·44	29.86	29·00	28·17	28·94	27·83	27·86	28·43	27·90	25·77	28·17	28·87	26·1	28
Fe'''	—	—	0·07	0·11	0·07	0·03	0·74	0·75	0·32	0·48	0·21	0·07	1·3	
B	1·77	3·36	3·51	3·95	3·59	4·08	3·78	3·86	3·61	3·81	3·37	3·66	3·3	4
R	0·57	0·07	—	—	0·42	—	0·57	0·57	0·51	1·10	0·70	0·06	—	—
Σ*	31·78	33·29	32·58	32·23	33·02	31·94	32·95	33·04	32·30	31·16	32·45	32·66	30·7	32
H_2O, %	1·34	1·72	1·41	2·14	1·52	2·09	2·12	2·12	1·32	1·27	1·29	1·00	0·4	0
Sp. gr.	—	—	3·319	3·226–3·43	3·306	3·211–3·302	—	—	3·309	—	3·28	3·27	3·41	3·390†

1, 2. Clip, Yuma Co., Arizona. J. E. Whitfield anal. in J. S. Diller, 1889; R = 0·30 Mg + 0·19 Na + 0·08 K in anal. 1, 0·07 P in anal. 2.
3. Clip, Yuma Co., Arizona. W. E. Ford, 1902.
4. San Diego Co., California. W. E. Ford, 1902.
5. Dehesa, San Diego Co., California. W. T. Schaller, 1905; R = 0·42 Ti; 2E = 33° Li, 37° Na, 42° Cu.
6. Harlem, New York City. W. E. Ford, 1902.
7. Washougal River, Skamania Co., Washington. W. T. Schaller, 1905; known to contain some sphene and some andalusite; R = 0·28 Ti + 0·29 Ca.
7*a*. Anal. 7 recalculated after deducting Ti and Ca as sphene (2½ %).
8. Ashby, Addington Co., Ontario. E. W. Todd anal. in T. L. Walker, 1922; R = 0·02 Ti + 0·04 Mn + 0·45 Mg; α 1·659, Berlin-blue, = [001], β 1·684 and γ 1·686 colourless; $2V_\alpha$ 52°.
9. Kuklík hill, Kutná Hora, Bohemia. J. Losert, 1956; R = 0·03 Ti + 0·25 Fe'' + 0·40 Mg + 0·01 Mn + 0·41 Ca; α 1·660 greenish-yellow, β 1·667 and γ 1·683 colourless.
10. Soavina, Ankofa, Madagascar. F. Raoult anal. in A. Lacroix, 1922; R = 0·19 Ti + 0·10 Fe'' + 0·10 Mg + 0·14 Ca + 0·14 Na + 0·02 K; α deep cobalt blue.
11. Mogra, Bhandara district, Central Provinces, India. S. K. Chatterjee, 1930; R = 0·06 Ti; α 1·678 deep lilac, β 1·685, and γ 1·688 colourless; H. 7.
12. Ceylon (B.M. 1953,76). This paper; for optical data see table I.
13. $4[(Al,Fe)_7BSi_3O_{18}]$.

* Sum of all atoms except Si and O. † Calc. for $Fe''' = 0$.

the effect of composition on refractive index; the highest refractive indices ever recorded for dumortierite are for the iron-rich Ceylon material (anal. 12), but it is difficult to see what the considerable difference between the refractive indices of the Kutná Hora (anal. 9) and Mogra (anal. 11) materials can be attributed to.

TABLE III. X-ray powder data for brown gem-quality dumortierite from Ceylon (B.M. 1953,76). Cu-$K\alpha$ radiation, camera diameter 6 cm.; the three strongest lines are numbered.

d,Å.	*I.*	*d*,Å.	*I.*	*d*,Å.	*I.*	*d*,Å	*I.*
5·85	s(1)	2·66	w	1·93	vvw(b)	1·476	vvw
5·06	m(2)	2·54	vw	1·871	vvw	1·463	vvw
4·26	mw	2·48	vvw	1·831	vw	1·449	vvw
3·84	mw	2·41	vvw	1·781	vw	1·334	mw
3·43	m	2·34	vw	1·729	vvw	1·297	w
3·33	vvw	2·24	vvw	1·656	vw(b)	1·267	vvw
3·22	m	2·19	vw	1·617	vw	1·247	vvw
3·07	w	2·09	ms(3)	1·544	vw(b)		
2·91	m(b)	2·01	vvw	1·506	vvw		

Among the most notable features of dumortierite are its deep colour, intense pleochroism, and wide range of colour. For vibrations parallel to β and γ it is commonly colourless or very pale yellow, but yellow (E. D. Wilson, 1929), orange-yellow (R. von Aubel, 1931), red-brown (this paper), and pale tints similar to α in hue have also been recorded, always with absorption $\beta > \gamma$. For vibrations parallel to α the commonest colour is deep cobalt-blue or deep Berlin-blue, but many other colours have been reported.[1] A. Damour (1881) suggested that the deep blue colour was due to a trace of Ti_2O_3, W. T. Schaller (1905) assigned the deep purple-red colour of San Diego Co. material to $1\frac{1}{2}$ % of Ti_2O_3, and A. B. Peck (1926) assigned the blue colours to Ti_2O_3 and the red to TiO_2, but the evidence to support these opinions is quite inadequate

[1] Purple-brown (A. Brammall, 1928; A. W. Groves, 1928); various hues of green (G. Linck, 1899; E. Rimann, 1914; T. L. Walker, 1922; J. Losert, 1956); various hues of crimson or violet (J. Romberg, 1893; H. Rösler, 1902; W. T. Schaller, 1905; E. Rimann, 1914; F. Němec, 1935); yellow (J. Losert, 1956); brownish-black (this paper). Also much lighter tints, from salmon-pink (A. Lacroix, 1893), lilac (S. K. Chatterjee, 1919, 1930), pink (F. MacMurphy, 1930), or pale blue-violet (E. S. Larsen, 1921) to pale yellow (J. Losert, 1956). The optical orientation is uniformly reported as α = [001], β = [010], γ = [100], except that S. Kilpady and A. S. Dave (1954) reported β = [100], γ = [010] for material from Garrah, India; but as they also report twinning on *m* {110} and cleavage *a* {100}, with $am = 61°$, whereas all other records show twinning on *m* {110} and cleavage *a* {100} with *am* about 30°, it seems more likely that their material had the normal optical orientation and twinning, but a cleavage or parting parallel to *b* {010} instead of the usual cleavage *a* {100}.

(cf. A. Lacroix, 1922, p. 402). N. L. Bowen and R. W. G. Wyckoff (1926) observed that blue material from Clip, Arizona, lost its colour at 800° C., but showed no appreciable change in the X-ray powder pattern. J. Losert (1956) observed that green Bohemian material when heated in air goes yellow, and suggested that this is due to oxidation of Fe″ to Fe‴, but does not appear to have brought analytical evidence to support this conclusion. The observed percentages of Fe and Ti in the deep-blue material from Clip and Harlem are very small, and it is doubtful if the origins of the colour of dumortierite can be satisfactorily explained in terms of colouring oxides; unusually stable colour-centres, perhaps connected with minor isomorphous replacements, seem a more probable cause, but the mineral is usually finely fibrous and intergrown with other minerals, making an identification of minor replacements very difficult.

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[1] A more complete bibliography up to 1956 has been prepared and deposited in the library of the Dept. of Mineralogy, British Museum.

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1914. E. Rimann, Centr. Min., p. 615 (occurrence at Copacabanca, Rio de Janeiro, Brazil; α deep blue, green, or violet).
1921. E. S. Larsen, U.S. Geol. Surv. Bull. no. 679, p. 70 (material from California gave α 1·670 pale blue-violet, β 1·691 and γ 1·692 colourless).
1922. T. L. Walker, Univ. Toronto Studies, Geol. Ser. no. 14, p. 80 [M.A. 2–39] (anal. 8).
—— A. Lacroix, Min. Madagascar, vol. 1, p. 401 (anal. 10).
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1926. N. L. Bowen and R. W. G. Wyckoff, Journ. Washington Acad. Sci., vol. 16, p. 178 [M.A. 3–187] (X-ray powder data and effect of heating on Clip material).
—— A. B. Peck, ibid., vol. 11, p. 96 [M.A. 3–315] (material from Limerick Canyon has α 1·675 red-violet to lavender blue, β 1·685, γ 1·692).
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1932. Univ. Nevada Bull., vol. 26, p. 98 (review and bibliography of occurrences in Nevada).
1935. F. Němec [Veda Prírodní, Praha, vol. 16, p. 287]; abstr. in M.A. 6–357 (occurrence near Velké Meziříčí, western Moravia; α 1·668, red-violet to crimson, γ 1·689 colourless).
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1954. S. Kilpady and A. S. Dave, Journ. Univ. Geol. Soc. Nagpur, vol. 1, p. 17 [M.A. 12–534] (occurrence at Garrah, Madhya Pradesh, India; α 1·68–1·69 dark blue, γ 1·70–1·71; abnormal optical orientation, see above).
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—— J. Losert, Rozpr. Česk. akad., vol. 66, p. 1 [M.A. 13–195] (review and bibliography of occurrences in Czechoslovakia; study of material from several occurrences near Kutná Hora; anal. 9).

The formation of supergene galena at Broken Hill, Northern Rhodesia.

(With Plate XXII.)

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[Read 23 January 1958.]

Summary. Lead–zinc ore-bodies in dolomite at Broken Hill, Northern Rhodesia, consist of a sulphide core surrounded by an oxidized sheath. Oxidation has been proved to persist to a depth of at least 1150 ft. below surface. In the transitional zone between sulphide and oxidized ore galena forms a thin rim to relict masses of blende, and farther into the sulphide core it penetrates the blende along cracks and cleavages. Locally it comprises over 5 % of the ore. From its relations to smithsonite and willemite it is clearly supergene in origin and must have been deposited above the water table. This considerable migration of lead in the zone of weathering is believed to have occurred during a former period of aridity.

THE lead–zinc–vanadium deposits at Broken Hill, Northern Rhodesia, occur in dolomites of the Middle Bwana Mkubwa Series (Katanga System). The five ore-bodies at present being worked vary from vein-like to pipe-like in form (Taylor, 1954). They are more or less completely oxidized above the 180-ft. level: at greater depths an irregular oxidized sheath surrounds a core of primary sulphides, consisting mainly of blende and galena with some pyrite and very subordinate chalcopyrite, bornite, and tetrahedrite. The oxidized ore is composed predominantly of smithsonite, willemite, cerussite, limonite, and quartz with smaller amounts of hemimorphite, pyromorphite, malachite, vanadinite, descloizite, and rare zinc phosphates (for details of the mineralogy see Spencer, 1908, 1927, and Taylor, 1954). Drilling has shown the persistence of a substantial amount of oxidation down to a depth of more than 1150 ft. There is considerable post-mineralization cavernization in the dolomite extending at least to the 850-ft. level. As the ground-water at the time when mining was commenced stood less than 50 ft. below the surface it is evident that the bulk of the oxidation must have taken place during some past period of low water table. Most probably this corresponded with the general period of aridity during which the Kalahari Sands were deposited in late Tertiary times.

Mode of occurrence.

The earliest stage of oxidation of the sulphides takes the form of penetration of blende along cracks, cleavages, and grain boundaries by irregular replacement veinlets carrying smithsonite, willemite, and sometimes quartz. These veinlets are commonly margined by a narrow rim of galena between 0·005 and 0·02 mm. in width. Pl. XXII, fig. 1, shows such a stringer passing in the south of the field into a wider veinlet (0·08–0·15 mm.) in which galena predominates with subordinate smithsonite. The highly irregular margins of the galena and the presence within it of little islands of blende leave no doubt as to the replacement origin of the veinlet. In the north of the field another widely occurring relationship is visible, a smithsonite–galena veinlet terminating in almost pure galena. Commonly replacement can be seen to have followed the cleavage of the blende (pl. XXII, fig. 2). Elsewhere it is highly irregular, and, in addition to the narrow galena border, the oxidation products of zinc have much galena scattered through them (pl. XXII, fig. 3). Some of this can be seen to be the remains of partially replaced grains of hypogene galena, but much is probably supergene. Little veinlets of galena, free of oxidation products, are not uncommon (pl. XXII, fig. 3) and are difficult to distinguish from hypogene replacements save where they carry a few grains of covelline, a mineral widely associated with the smithsonite–willemite–galena veinlets though always in very small amounts.

With increasing oxidation the blende becomes more and more dissected by replacement veinlets. Commonly these carry central willemite bordered by smithsonite, margined in its turn by galena (Taylor, 1954, pl. II, fig. 3). In some cases smithsonite has pseudomorphed blende, preserving traces of its cleavage. The presence, between the smithsonite and the residual core of blende, of the usual thin zone of galena shows that galena is without question the latest mineral in the sequence.

Where oxidation has gone almost to completion, the only relics of blende are highly irregular islands set in a sea of oxidation products and bounded by a thin galena rim (pl. XXII, fig. 4). Occasionally the rim contains some very subordinate covelline. Throughout the highly oxidized ore the presence of irregular corroded remnants of primary galena surrounded by smithsonite, willemite, and quartz bears witness to the lead that has gone into solution.

Thin rims of galena separating blende from oxidation products have been observed from every level in the mine where sulphide ore is worked

and are the rule rather than the exception. In the highly oxidized ore above the 180-ft. level they are less widespread and residual blende is commonly in direct contact with the replacing smithsonite and willemite. There can be no doubt of the supergene origin of the galena and it appears that the downward-percolating solutions universally carried some lead which, wherever conditions ceased to be strongly oxidizing, was precipitated by blende, displacing the more active zinc.

Locally the transition from primary sulphide ore to completely oxidized ore is effected in a matter of inches. More generally it forms a zone several feet in width. Micrometric analyses show that, within this zone, 5 % of galena of undoubted supergene origin is common and 8 % or more not unusual. Among a number of specimens chosen for analysis one 7 ft. from the margin of the completely oxidized zone (No. 3/4 ore-body, 350-ft. level) yielded 5·3 % of supergene galena, while another 9 ft. from wholly oxidized ore (No. 5/6 ore-body, 650-ft. level) carried 1·2 %. On the conservative assumption of a zone 3 ft. wide and containing 2 % of supergene galena, margining the sulphide cores of all the ore-bodies between the 180-ft. and 750-ft. levels in the mine, a rough approximation shows that something over 5 000 tons of lead has been transported in solution and reprecipitated as the secondary sulphide. This lead, however, is distributed over a big vertical interval and it does not necessarily follow that any of it has been transported a great distance. From the relations of the secondary galena to the oxidation products of zinc it is clear that it was formed above the water table at the advancing front of oxidation into the ore-bodies, in a manner which is familiar in the case of supergene copper sulphides and has been notably described by Lindgren (1915) at Tintic in Utah.

Other records of secondary galena.

As Lovering (1934) has pointed out, 'galena is tacitly assumed to be primary unless there is strong evidence to the contrary'. There are relatively few records of galena of undoubted supergene origin supported by petrographical details. It has been clearly described from Broken Hill, New South Wales, where Stillwell (1927) refers to blende being intersected by veins of zinc carbonate margined by galena. It occurs in the lead–zinc–vanadium deposits of Abenab West in South-West Africa (Verwoerd, 1957). Here the whole mineralogy, which includes willemite, vanadinite, and descloizite, as well as the mode of occurrence of the secondary galena, closely parallels Rhodesian Broken Hill. At Balmat in northern New York State, Brown (1936) has described secondary galena

which is accompanied by willemite, replacing blende and pyrite along cracks and cleavages. Each of these three cases is associated with a deep oxidation zone.

At Lake City, Colorado, Irving and Bancroft (1911) recorded the presence of a 'thin grey film, believed to be galena', deposited in cracks in shattered blende in the oxidation zone. At Breckenridge, Colorado, Ransome (1911) claimed that there had been substantial supergene precipitation of galena. He did not, however, produce any supporting mineralogical evidence and Lovering (1934) regarded most of the galena as primary. Wang (1916), in the course of a study of the oxidation products of zinc, described and illustrated galena rims to residual grains of blende surrounded by smithsonite, from an unspecified locality in north-western Arkansas.

Conditions of formation.

The limited mobility of lead in the zone of weathering is generally attributed to the formation of a sparingly soluble coating of sulphate or carbonate on galena preventing further oxygen from reaching it. In pure water the carbonate is the least soluble compound but in water saturated with carbon dioxide, as might be anticipated in the presence of a limestone or dolomite country rock, its solubility is considerably increased. Garrels (1954) has calculated the activity (at 25° C.) of lead ion in equilibrium with carbonate, sulphate, and sulphide on the assumption that the ground waters are saturated with carbon dioxide and the concentration of soluble sulphur is 10^{-1} mols per litre. The activity of lead ion in equilibrium with sulphate is much less than that with the other anions, so, for these conditions, lead sulphate is presumably the most stable (least soluble) mineral.

Garretty and Blanchard (1942) studied the effects of post-mine leaching on the ore at Australian Broken Hill and came to the conclusion that, contrary to expectation, the galena was being leached more rapidly than the blende. They attributed this to the fact that little or no anglesite was being formed and suggested that this might be in consequence of a general weakness of ferric sulphate solutions, resulting from the low pyrite content of the primary ore. Some confirmatory evidence of this comes from Mount Isa in Queensland where Grondijs and Schouten (1937) found that galena had been most completely leached from those parts of the ore-body poor in pyrite and pyrrhotine. Where these minerals were plentiful, on the other hand, galena remained behind partially altered to anglesite. Pyrite is a relatively minor constituent

at both Rhodesian Broken Hill and Abenab West and anglesite is rare or absent. It may be that the solution of lead is best accomplished in the absence of the concentrated ferric sulphate solutions so destructive to other sulphides. Where oxidation is the work of weaker and possibly less acid solutions, time and temperature must inevitably be factors of importance. At Rhodesian Broken Hill the ores crop out on the great central African plateau, an erosion surface of Tertiary date, or earlier, and in a position less than 15° S. of the equator.

The present-day mine waters at Rhodesian Broken Hill are carbonate–sulphate waters with the relatively low salinity of 98 parts per 100 000 and a pH of 6·6–7·2. They carry only 0·02 parts per 100 000 of lead. However, the region has recently emerged from a period of aridity when the water table was at least 1000 ft. lower than it is today. The effect of aridity on ground waters is normally to increase greatly the concentration of dissolved salts, especially that of chlorides (Robaux, 1953). The presence of chlorides substantially increases the mobility of lead. The widespread presence of pyromorphite and vanadinite at Rhodesian Broken Hill provides evidence that the chloride ion must have been present, as, from the mineralogy, it must have been also at Abenab West and Australian Broken Hill.

It has already been suggested (Taylor, 1954) that the development of vanadates and of willemite (in place of the more normal hydrated silicate hemimorphite) in the oxidation zone at Rhodesian Broken Hill are consequences of prolonged weathering under hot arid conditions. It appears that the widespread deposition of supergene galena was due to similar factors, aided perhaps by the relative scarcity of pyrite in the primary ore. These conditions would also explain its occurrence at Abenab West and Australian Broken Hill. At Balmat pyrite is plentiful and despite the great depth of the supergene zone there is no direct evidence of arid conditions or of chlorides in the ground-water. There is, however, no reason to believe that the formation of secondary galena is always related to one set of conditions. In humid climates it may well be some factor such as the concentration of organic acids that controls the stability of lead in the zone of weathering.

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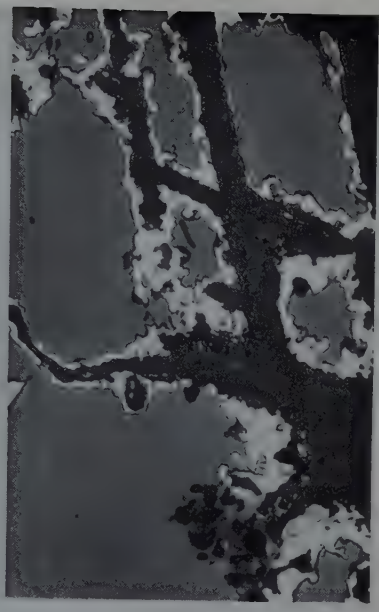

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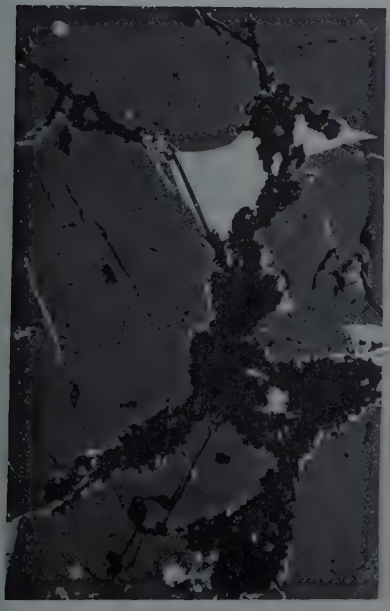

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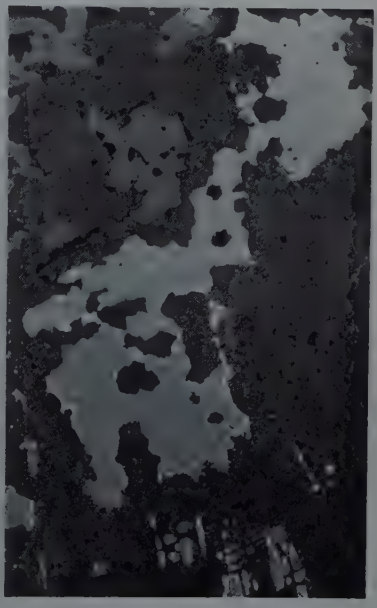

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J. H. Taylor: Supergene galena, Rhodesian Broken Hill

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Explanation of Plate XXII.

Photomicrographs of polished sections of ore from Broken Hill mine, Northern Rhodesia, showing development of supergene galena.

Fig. 1. Blende (grey) is cut by 0·07 mm. wide replacement veinlet of smithsonite (darker grey) with narrow margins of galena (white). In the south of the field this passes into an irregular veinlet consisting largely of galena with subordinate smithsonite and a few residuals of blende. In the north a short smithsonite–galena veinlet can be seen to terminate in pure galena. Hypogene galena occupies the extreme north-east corner. No. 3/4 ore-body, 350-ft. level, Gut Drive east. ×75.

Fig. 2. Blende (grey) is replaced along cleavages by smithsonite and willemite (dark grey) with marginal galena (white). In the south of the field a little covelline (light and dark grey with a rather hazy appearance) is associated with the galena. No. 3/4 ore-body, 350-ft. level, Gut Drive east. ×180.

Fig. 3. Blende (grey) and primary galena (white) are replaced by smithsonite (dark grey) with narrow zone of supergene galena separating smithsonite from blende. Thin veinlets of pure galena are presumably also supergene. A considerable amount of galena is scattered through the smithsonite but it is difficult to say how much is supergene and how much merely relics of largely replaced hypogene galena. No. 3/4 ore-body, 550-ft. level, 11 west cross-cut. ×55.

Fig. 4. Highly irregular residual island of blende (light grey) surrounded by narrow border of (white) galena in a sea of replacing smithsonite (darker shades of grey). Where blende is replaced centrally by smithsonite the two are separated by the usual galena rim. In the south of the field replacement has followed cleavages of the blende. No. 1 ore-body, 550-ft. level, 8 west cross-cut. ×40.

The effect of composition and structural state on the rhombic section and pericline twins of plagioclase felspars.

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[Read 5 June 1958.]

Summary. The position of the rhombic section of plagioclase felspars, as calculated from the measured cell dimensions, has been shown to vary with the structural state, the variation from high- to low-temperature forms being most pronounced for albite. The theoretical composition plane of pericline twins is the rhombic section. If the structural state or the composition of the felspar changes after twinning has occurred, the cell dimensions and hence the rhombic section will change; however, the composition plane of the pericline twin will probably remain unchanged unless recrystallization occurs, or perhaps if the felspar is subjected to strong stress. Thus the observed pericline composition plane need not coincide with the rhombic section. Comparison of observed composition planes with the corresponding calculated rhombic sections shows that some of them do indeed differ and the differences have been used to provide information on the changes occurring subsequent to the establishment of the pericline twins. The interpretation is complicated by the occurrence of the acline-A twin, whose composition plane is {001}, for the rhombic section of plagioclase felspars from An_0 to An_{60} may coincide with {001} if the structural state of inversion has a particular value. When the observed composition would agree with both pericline and acline-A twinning, the new term *b-axis twin* has been used.

THE composition plane of the pericline twin, the rhombic section, has been the subject of many investigations over the past 120 years and it has usually been implicitly assumed that its orientation has been controlled by only one factor, the chemical composition. It is the purpose of this paper to show that the position of the rhombic section is mainly controlled by two factors, chemical composition and structural state.[1] Many interpretations of the observations on the pericline twin of plagioclase felspars are in conflict and it will be shown that these conflicts can be resolved when the effect of differing thermal history is considered.

Properties of pericline and acline-A twins.

Both pericline and acline-A twins are parallel twins with the *b*-axis as the twin axis: their respective composition planes are the rhombic

[1] Called 'thermal state' in earlier papers on plagioclase felspars.

section and the (001) plane. The rhombic section is an irrational plane that contains the *b*-axis and intersects the (010) plane in a line normal to the *b*-axis. Its orientation is conveniently specified by giving the angle σ between the *a*-axis and the trace of the rhombic section on the (010) pinacoid. When the lattice angles are such that $\sigma = 0°$, the pericline and acline-A twins are identical, a possibility of considerable practical importance. It is not possible to distinguish the pericline and acline-A twins by X-ray methods since diffraction of X-rays is not influenced by the composition plane. For these reasons, the noncommittal term *b-axis twin* is introduced for use when the twin axis but not the composition plane has been characterized.

Effect of structural and compositional changes.

Whereas the composition plane of the acline-A twin is a crystallographic constant and independent of physical variables, the rhombic section, being a function of the lattice angles, depends on the composition and the physical conditions. Although the rhombic section and the pericline composition plane, theoretically, must be parallel when the twin lamellae are established, it is not necessary that they remain parallel; for the lattice angles, and hence the rhombic section, may subsequently change in response to structural and compositional changes, while re-orientation of the composition plane would involve such a drastic movement of the felspar lattice that it is likely that adjustment could occur only upon recrystallization, or perhaps under the influence of shearing force. If recrystallization occurred, the new composition plane would be controlled by the new rhombic section. The operation of shear forces might help to re-orient the lamellae, for Mügge (1930) has produced pericline twinning in anorthite by the application of shear force and Phillips (1929) has noted the prevalence of pericline twinning in low-grade metamorphic schists that have been subjected to stress. Structural changes resulting from the movement of Si, Al, Ca, and Na atoms would probably not induce re-orientation of the composition plane. Anisotropic thermal contraction would give rise to angular movements too small to be of practical significance.

Prediction of the orientation of the rhombic section.

The angle σ is a function of the cell angles and may be calculated from the relation $\cot \sigma = \cos \alpha^* / \cot \gamma$ (Story-Maskelyne, 1895) where α^* is the angle between the (010) and (001) face normals. The single crystal X-ray studies of Cole, Sörum, and Taylor (1951) and the powder X-ray

investigation of Smith (1956) have provided accurate values of the lattice angles for the composition range An_0 to An_{55}. In the remaining range, only one complete set of lattice angles has been determined by X-ray methods, unfortunately for an unanalysed specimen. Study of the morphological data in the literature has led to the conclusion that most of it is of considerably lower accuracy than the X-ray data and should be disregarded. Of the six direct and reciprocal lattice angles, only α^* can be determined directly by morphological examination. The indirect procedure for determining the other angles has been so uncertain that resort has been made sometimes to the dubious procedure of calculating γ from measured values of (010):(001) and σ by the formula given at the head of this section. In spite of these difficulties, several sets of fairly accurate data have been obtained by morphological methods.

The results of the X-ray and morphological studies are displayed in fig. 1. From An_0 to An_{35}, the data are sufficient to establish the influence of the structural state and chemical composition on the orientation of the rhombic section. All but three of the natural specimens from low-temperature environments give a linear dependence betweeen σ and the An-content. The remaining three are albites that have been examined morphologically and the deviations are probably caused by errors resulting from the presence of vicinal faces. The rhombic section for the synthetic specimens is almost independent of An-content. Seven specimens illustrate the conversion by heating from the low-temperature to the high-temperature state while two specimens of andesine from volcanic environments reveal a state of partial inversion. These two specimens are of particular interest because their rhombic sections are so close to (001) that, in practice, it would be impossible to distinguish between pericline and acline-A twins.

The 'oligoclase' from Vesuvius, listed by Dana and by Hintze as the type oligoclase, is better described as a lime-bearing anorthoclase because its composition is $Or_{16}Ab_{69}An_{15}$ and the lattice angles agree with those expected for a high-temperature structure. It has been included to show that the solid solution of potash has little effect on the position of the rhombic section of high-temperature acid plagioclases. The calculations of MacKenzie (1956) for synthetic lime-free anorthoclases revealed the same independence of potash content. Data obtained by MacKenzie and Smith (1955) from experiments in which perthites of low-albite and potash felspar were heated can be used to demonstrate that the rhombic section of low-temperature acid plagioclases is also independent of the solid solution of potash felspar. From their measurements of the change

of α^* and γ^* produced by the introduction of potash into the perthitic albite, and the data given by Smith (1956), it is likely that low-temperature felspars of composition Or_5Ab_{95} and $Or_5Ab_{85}An_{10}$ will have the following lattice angles respectively: α^* 86·60°, γ 87·68°; α^* 86·51°, γ 88·17°;

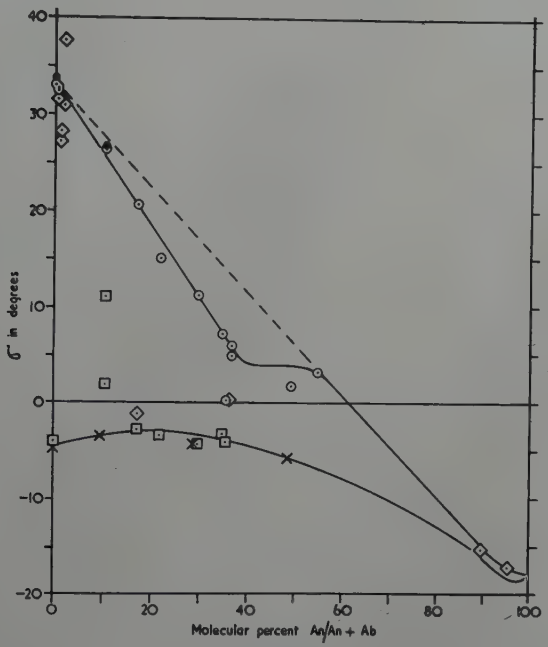

FIG. 1. The variation of σ with composition and structural state of plagioclase felspars. ○ natural, lattice angles from X-ray studies; ◇ natural, angles from morphological studies; □ heated natural; × synthetic; ● hypothetical felspars of composition Or_5Ab_{95} and $Or_5Ab_{85}An_{10}$. The upper and lower full-line curves, respectively, give the variation of σ with composition for specimens in the low and high structural states. Smith and Gay (1958) have suggested that fully ordered sodic plagioclases would fall on the broken-line curve and that the low-temperature specimens in this region are not fully ordered. The sources of the data are Cole, Sörum, and Taylor (1951), Des Cloizeaux (1862), Fels (1903), Glinka (1889), Kratzert (1921), Krebs (1921), Lewis (1914), vom Rath (1869, 1886), Smith (1956).

the positions of the rhombic section calculated from these angles hardly differ from those of corresponding natural plagioclases containing only 1 or 2 % potash felspar. As basic plagioclases carry only small amounts of potash felspar in solid-solution the effect of potash felspar on the rhombic sections of all plagioclases may be safely ignored.

The data on the lattice angles of intermediate and basic specimens are

sparse; however, a recent X-ray study of the powder patterns by Smith and Gay (1958) yields supplementary information. Two good sets of morphological data on analysed basic plagioclase specimens are available: An anorthite from Vesuvius gave $\sigma = -17° 09'$ in good agreement with the value $-16° 45'$ obtained from the X-ray measurements of an unanalysed specimen from the same locality; although from a volcanic environment, it is probably in or near the low structural state (cf. Gay 1954). The bytownite from St. Christopher's Island is from a volcanic environment and comparison with specimens from other localities described by Gay (1954) suggests that it is probably in a transitional state.

Examination of the variation of the lattice angles with composition shows that the change in position of the rhombic section is largely caused by the variation in γ, for $\cot\sigma = \cos\alpha^*/\cot\gamma$ and $\cot\gamma$ ranges from $+0{\cdot}04$ to $-0{\cdot}02$ while $\cos\alpha^*$ ranges from $+0{\cdot}063$ to $+0{\cdot}073$. Consequently, examination of the movement of those peaks in the X-ray powder pattern that depend strongly on the lattice angle γ^* can provide information on the position of the rhombic section. Smith and Gay have recorded such information in their study of more than 100 plagioclase felspars, including all those used in fig. 1 of this paper. Examination of the figures and data show that, for the acid plagioclases, the variation in the rhombic angle σ is closely paralleled by the change in the Γ function measured by Smith and Gay. This function depends largely on γ^*, but also gives a good measure of γ, for γ varies in a proportional manner to γ^* for plagioclase felspars. Hence the orientation of the rhombic section and the Γ function would be expected to vary in a similar manner. The curves for the intermediate and basic ranges of fig. 1 have been obtained by using the few direct observations in conjunction with the observed variation in the Γ function. In spite of its indirect origin, this curve is thought to give a fairly accurate representation of the variation in the position of the rhombic section.

All the data used in the construction of fig. 1 were obtained at room temperature, so, strictly speaking, the predicted rhombic sections apply only to twin development at room temperature. Direct measurements of the variation of lattice angles with temperature have not yet been made, apart from some observations on anorthite. However, the influence of temperature—as distinct from the structural state—on twin formation may be estimated in a qualitative or semi-quantitative way. MacKenzie (1952) and Laves (1952) have shown that lime-bearing anorthoclases become monoclinic at high temperature, which means that α^* and γ probably approach 90° at the same fractional rate. As $\cot\sigma = \cos\alpha^*/$

$\cot\gamma \approx (90-\alpha^*)/(90-\gamma)$ when α^* and γ are near 90°, the rhombic section of any particular anorthoclase should be independent of temperature. This is confirmed by the agreement between the observed composition plane of pericline twins and the rhombic sections calculated from lattice angles that have been measured at room temperature (MacKenzie, 1956). Although high-temperature potassic oligoclases do not become monoclinic on heating to high temperatures, α^* and γ approach 90° as the temperature is increased (MacKenzie, 1952), and it is reasonable to suppose that α^* and γ approach 90° at the same fractional rate since there is a continuous change from potassic oligoclases to calcic anorthoclases. Thus the rhombic section of high-temperature acid plagioclases should be independent or nearly independent of temperature. Some unpublished powder X-ray measurements made by the author on low-temperature albites indicated that the change of lattice angles upon heating was moderate. As the low-temperature state is probably only formed at low temperatures it is likely that the rhombic section for low-temperature acid plagioclases is nearly independent of temperature. Mügge (1932) has shown from the lattice angles obtained by Beckenkamp that the rhombic angle of an anorthite from Vesuvius increased by 25′ as the temperature increased from 20° C. to 200° C. This suggests that the rhombic angle for low-temperature anorthite may increase by as much as 2° as the temperature of crystallization goes up to 700°–1000° C., the upper limit for the primitive anorthite type of structure (Gay, 1956). No data on high-temperature basic plagioclase specimens are available.

Therefore, for a particular structural state, it is probable that the influence of temperature on the rhombic section is small and for most practical purposes may be ignored.

Fig. 1 is suitable for the interpretation of values of σ obtained by direct measurement on the face (010), or on sections cut parallel to (010). Nowadays, however, most measurements of plagioclase twins are made optically from sections suitably orientated on a universal-stage, and the twin-elements are referred to the optical indicatrix. Figs. 2 and 3 have therefore been prepared to show the predicted orientations of the (001) plane and the pericline composition plane with respect to the principal optic symmetry axes α, β, and γ for the extreme low and high structural states respectively. The positions of the (001) pole have been taken from van der Kaaden (1951) who obtained them from consideration of observations on synthetic and natural plagioclases obtained by himself and other workers. The definition of σ as the angle between the intersections

of the (001) plane and the rhombic section on the trace of (010) implies that the pole of the rhombic section may be located by using the positions of (010), [010], and (001) given by van der Kaaden and the values of σ given in fig. 1. Using this construction, figs. 2 and 3 have been prepared. Fig. 2, for specimens now in the low-temperature state,

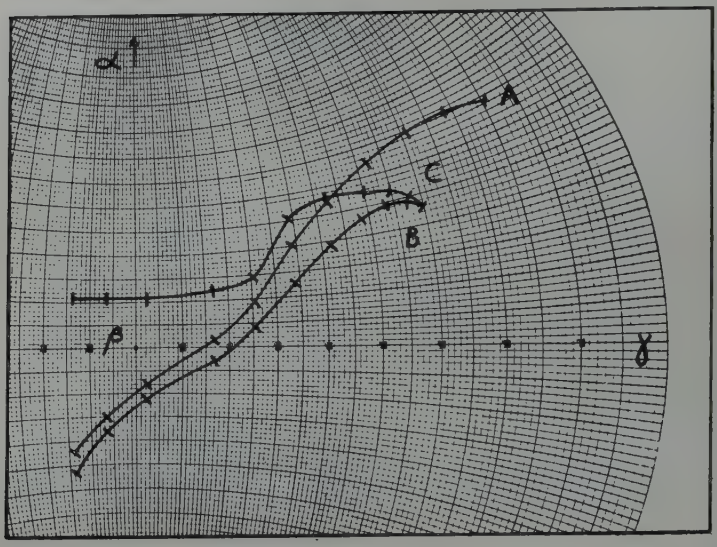

FIG. 2.

FIGS. 2 and 3. The orientation of the pericline composition plane, the rhombic section, and the (001) pole relative to the optical indicatrix of plagioclase felspars. *A*, the (001) pole; *B* and *C*, pericline composition planes, *B* for twinning established while the felspar was in the high structural state and *C* for twinning established while it was in the low structural state, and assuming in either case that any subsequent inversion has not affected the composition plane. Fig. 2 (*above*) is for felspars now in the low structural state and the rhombic section is given by curve *C*. Fig. 3 (*opposite*) is for felspars now in the high structural state and the rhombic section is given by curve *B*. The cross-marks indicate the compositions An_0, An_{10}, ... An_{100} running from left to right. Based on van der Kaaden (1951) and fig. 1.

contains one curve for (001) and two curves for the predicted pericline composition plane, one each for twinning controlled by the high and low structural states. Fig. 3, for specimens now in the high-temperature state, contains three curves; if the felspar crystallizes with the high-temperature structure and no inversion occurs, curves *A* and *B* give the positions of the (001) pole and the rhombic section, respectively. As it is possible that the felspar once had the low-temperature structure and has

inverted as a result of high-grade metamorphism, curve *C* is given to show the predicted position of the composition plane for twinning occurring before inversion. Fig. 4 shows the regions that may be occupied by the (001) pole and the pericline composition plane for all possible compositions and structural states.

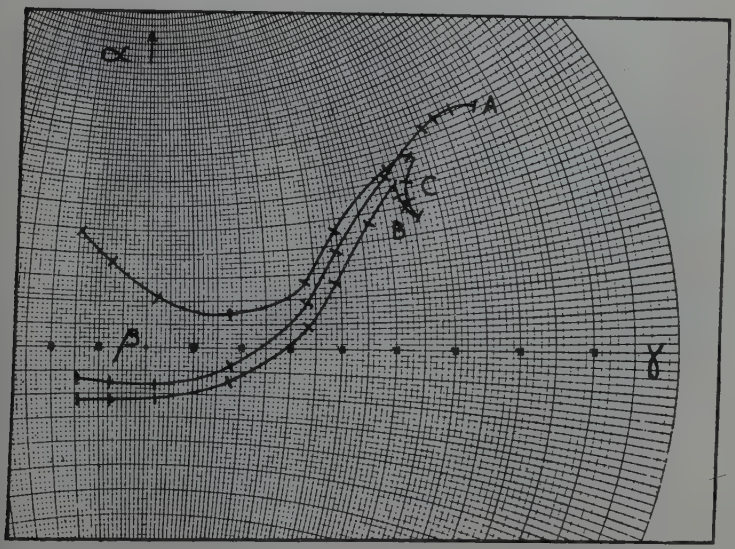

Fig. 3.

Interpretation of the observations.

The goniometric and universal-stage measurements of the composition planes of *b*-axis twins are displayed in figs. 5, 6, and 7. High accuracy cannot be expected for all the measurements because the composition plane of pericline twins is often irregular (e.g. Gysin, 1925), while the occasional use for reference of positions of (001) taken from standard optical migration curves may lead to further uncertainty. The universal-stage measurements are plotted in two groups: those in fig. 6 arise from plagioclases whose environment indicates a low structural state, while those in fig. 7 come from volcanic or hypabyssal specimens of uncertain structural state. In fig. 6 it is necessary to plot only three reference curves: (001), the rhombic section for the low structural state, and the relict rhombic section for the high structural state. In fig. 7 it is necessary to show two additional curves to cover the possibility of plagioclases

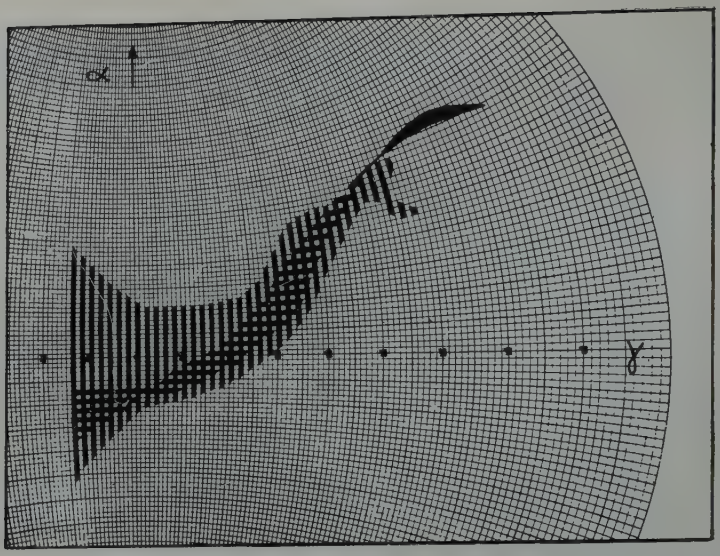

FIG. 4. The possible positions of the (001) pole and of the pericline composition plane with respect to the optic symmetry axes α, β, and γ for all compositions and structural states. The horizontal shading represents the (001) pole and the vertical shading the pericline composition plane.

not in the low state; the two extra curves show the regression of (001) and the rhombic section for the high state (the possibility of high-grade metamorphism of an original low plagioclase is ignored, thus permitting the omission of the relict rhombic section for the low structural state).

If all the plagioclases had reached equilibrium, and if acline-A and pericline twins adopted the theoretical composition planes, the composition planes of *b*-axis twins would be parallel to either (001) or the rhombic section of the low structural state. The observed data fall only partly on these two theoretical planes and the deviations might be caused by one or more of the following: experimental error, structural inversion or change of chemical composition, initial adoption of a composition plane other than (001) or the rhombic section. Examination of the figures shows that a few values for albite specimens and many values for bytownites and anorthites are not consistent with either (001) or the rhombic sections. The deviations for albite cannot be explained as the result of either compositional or structural changes, and it seems likely that they result merely from experimental error in the measurement of α

or in the location of the reference curves for (001) and the rhombic section. The discrepancies for the basic specimens (fig. 5) are more prominent, but the deviations are probably more apparent than real, for

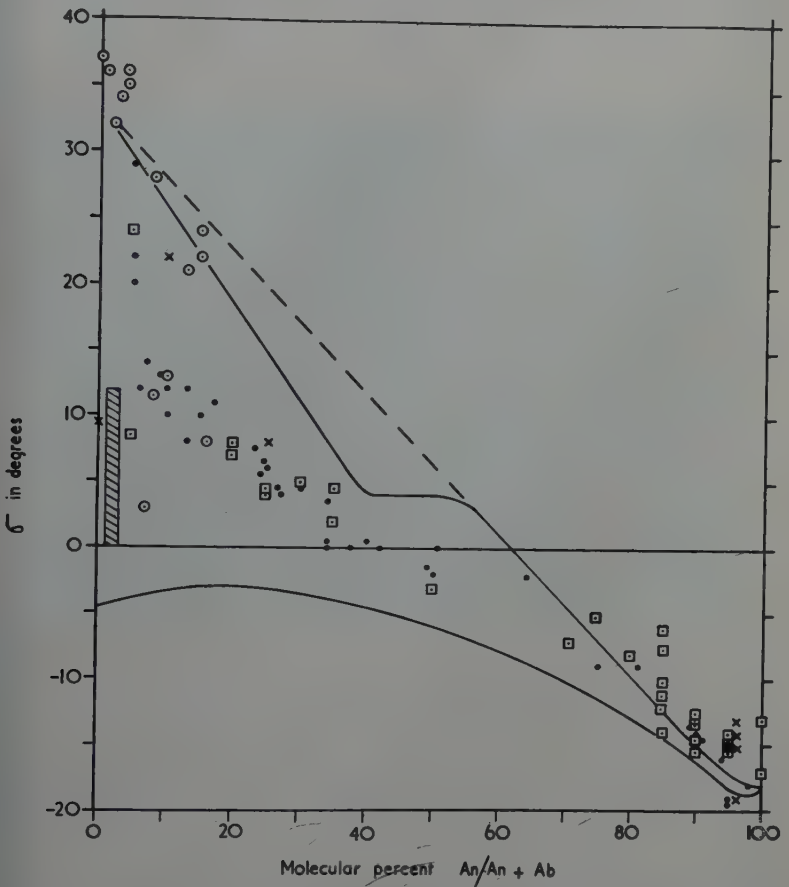

FIG. 5. Comparison of observed σ values with the theoretical curves. ○ Barth (1928); ● Schmidt (1915); □ Barber (1936); ×, in order of An-content, Penta (1933), Glinka (1894), Crawford (1926), and Mügge (1930). The shaded area covers the range of values obtained for albites from Alpine schists by Lewis (1914) and by Smith.

most of the chemical compositions were estimated optically and listed only to the nearest 5 % An (Barber, 1936). In addition the theoretical variation of σ for these compositions is uncertain. Thus the conclusion reached by vom Rath in 1876, that the pericline twin adopts the rhombic

section for its composition plane, is confirmed, though not as conclusively as might be desired.

Examination of the figures shows, in agreement with Gysin (1925), that a clear distinction can be made between acline-A and pericline twins for specimens more basic than An_{70}. Over the range An_0 to An_{60}, many of

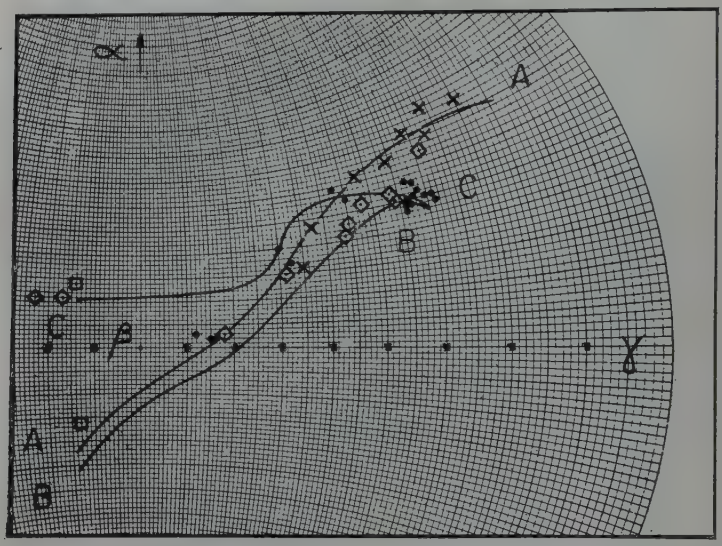

Fig. 6. Comparison with the theoretical curves for pericline and acline-A twins of the observed composition planes for plagioclases that are probably in the low structural state. □ Phillips (1929); ◇ Dolar-Mantuani (1952, the two sodic specimens), Hermann (1924, the eight more calcic specimens); ● Gysin (1925); × Bradley (1953). The points should lie on curve *A* for acline-A twins, on curve *C* if twinning was established with the felspar in its present state, and on curve *B* if twinning was established while the felspar was in a high structural state and the composition plane was not affected by subsequent inversion.

the specimens cannot be assigned with certainty to either twin law as the observed composition planes do not differ from (001) by more than the possible experimental error. The others may be unambiguously assigned to the pericline type and the observed value of σ in relation to the theoretical curves may be used to obtain some information about the state of the felspar at the time twinning occurred.

The albites and oligoclases from microcline perthites, with one exception, give values that lie on or close to the theoretical rhombic section for the low structural state. This is to be expected whether the albite

forms by exsolution or replacement. The exception has $\sigma = 3°$ and could either be an acline-A twin with a 3° error of observation (as suggested by Phillips, 1929) or a pericline twin controlled by a structural state close to the extreme high state; the latter would not be surprising, for MacKenzie and Smith (1955, and unpublished) have found that some

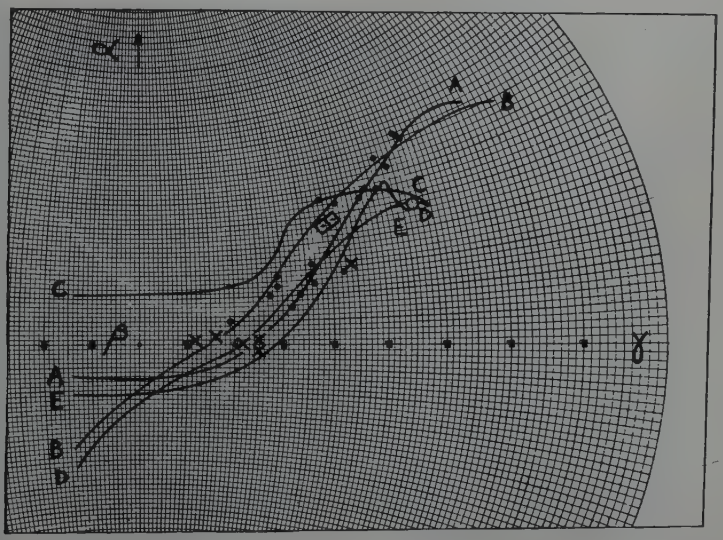

FIG. 7. Comparison with the theoretical curves for pericline and acline-A twins of the observed composition planes for plagioclases that may be either in or between the high and low structural states. × Bradley (1953); ● Gysin (1925); ◇ Campbell Smith (1928); ○ Lundegårdh (1941). Curves *A* and *B* give the position of the (001) pole for the high and low structural states, respectively. Curves *C* and *E* are the rhombic sections for plagioclase felspars in the low and high structural state, respectively. Curve *D* gives the pericline composition plane for a felspar in which the pericline twinning was established while the felspar was in the high structural state and in which subsequent inversion to the low structural state did not affect the composition plane.

rare microcline perthites contain an anorthoclase, which has a rhombic section similar to that of high albite.

The possibility of compositional changes complicates the interpretation of the observed twin relations, for a change of composition unaccompanied by a corresponding movement in the composition plane results in a composition plane consistent with a different structural state. Fortunately, compositional changes in the plagioclases of igneous rocks

are probably rare, as the persistence of fine-scale zoning indicates. In veins, and possibly in metamorphic rocks if recrystallization does not occur, compositional changes subsequent to the establishment of the twin boundary may be important. Thus Professor F. Laves and Dr. T. Schneider of Zürich have recently[1] provided evidence for compositional changes in the variety of albite known as pericline that occurs in cavities in Alpine chlorite–albite schists. They found that the σ angles in the pericline twins are commonly 9°–10°, that the crystals are milky in appearance, containing holes and enclosures, that the extinction is irregular, and that the pericline often has a clear shell of albite. Measurements by Lewis (1914) and by the present author are in accord with those of Laves and Schneider. Lewis described a pericline triplet with a σ angle ranging from 7·5° to 11°, while the present author has found various values for specimens in the Cambridge museum ranging from 0° to 20° with averages taken over a single specimen ranging from 0° to 12°. X-ray powder measurements have invariably indicated a low structural state with a composition close to pure albite. Laves and Schneider concluded that it was likely that pericline crystals were once oligoclase but have suffered a change of composition that has led to their irregularity of texture and extinction. The alternative, that the pericline grew as albite in a high or intermediate structural state, is regarded as unlikely. The present author agrees with this view but nevertheless believes that some of the intermediate σ angles of other albites and oligoclases (see fig. 5) definitely indicate twinning while the plagioclase was in a high or intermediate structural state, since the original descriptions give compositions ranging all the way from An_0 to An_{30} and many of the specimens do not have the characteristics of the Swiss pericline.

So long as compositional changes can be ruled out, the possibility exists of demonstrating changes of structural state in pericline-twinned plagioclase. The present structural state can readily be estimated by X-ray, infra-red, and optical methods, while the pericline composition plane provides evidence of an earlier structural state. Examination of figs. 5, 6, and 7 shows that the effect of structural state on the composition plane falls off rapidly with the An-content and that estimation of the original structural state is, in practice, confined to plagioclase in the albite–oligoclase range, though in favourable cases some indication might be obtained for andesine and labradorite.

In conclusion, it should be emphasized that many qualitative and semi-quantitative arguments have been used in this paper, which may not

[1] Preliminary summary in Schweiz. Min. Petr. Mitt., 1956, vol. 36, p. 622.

stand the test of further experimental investigation. Accurate measurements of the cell dimensions of basic plagioclases, both at ordinary and elevated temperatures, together with measurements of sodic plagioclases at elevated temperatures, are needed both for the present and other purposes. A systematic study of pericline-twinned plagioclases, obtained from known petrological environments, is needed to provide a more rigorous test of the predicted orientation than the one given in this paper. The author hopes that the present account will provide the stimulus for such investigations.

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Variation of refractive index with ionization potential in some isostructural crystals.

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Summary. A closer understanding of the causes for the variation of refractive index with change of composition has been sought in terms of certain properties of ions. The study is confined to isostructural ionic crystals. It is assumed that polarization of the anions (usually O^{2-} or F^{-}) makes the principal contribution to the total refractive index effect, and that variation of refractive index is determined mainly by variable anion polarization. Polarization of the anion is controlled largely by the field in which it finds itself which, in turn, depends on the effective force of attraction of the cation: ionization potentials are used for the purpose of comparing such forces. For compounds involving pairs of 8- and 18-electron cations (Mg^{2+} and Zn^{2+}; Al^{3+} and Ga^{3+}; Si^{4+} and Ge^{4+}; Ca^{2+} and Cd^{2+}) or pairs of transition cations (Zr^{4+} and Hf^{4+}; Nb^{5+} and Ta^{5+}; Mo^{6+} and W^{6+}) refractive indices are higher in the crystal that contains the cation of the element with the higher ionization potential. For larger suites of cations of various types (for example, Mg^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, and Zn^{2+}, radii from 0·65 to 0·80 Å.) the predicted relationship between ionization potential and refractive index holds precisely for the compounds $A^{2+}SiF_6.6H_2O$ ($A^{2+} = Mg^{2+}$, &c.), but only in part for other compounds; this may be due to the effect of the crystal field on certain 3*d* transition cations.

MANY authors have discussed variation of refractive index with composition: Barth (1930), Hess (1949), Kennedy (1947), Hori (1954 and 1956), Jaffe (1956), and Larsen (1921 and 1934) are a few examples in mineralogy. The present paper is also concerned with the general problem of variation of refractive index with composition: its main purpose will be to seek a closer understanding of the physical causes of the variation of refractive index in ionic crystals.

The refractive index of a crystal depends mainly on its structure (Hori, 1954 and 1956, for example) and certain intrinsic properties of its component atoms or ions (Fajans and Kreidl, 1948, who refer to several earlier publications of Fajans and co-workers). If we consider isostructural ionic crystals only and confine ourselves to examining *variation* of refractive indices in suites of such crystals (the olivines, for example), it is necessary to consider only the properties of the ions in question. Under these conditions and for the purpose of this study the refractive index itself rather than the molar refraction will be used.

In ionic isostructural crystals, variation of refractive index should reflect the average state of polarization of the constituent cations and anions; the greater the degree of polarization (deformation), the greater the interaction with the passage of light waves and the higher the refractive index. The familiar generalization that anions are much more easily polarized (deformed) than cations may be assumed to be valid provided large and singly charged cations (Na^+, K^+, Rb^+, Cs^+, NH_4^+, Tl^+, and Ag^+) are omitted. Accordingly, in crystals other than those involving large singly charged cations, polarization of the anion should make the major contribution to the total refractive index because polarization of the anion will be far greater than that of the cation. The degree of polarization of the anion depends on the field in which it finds itself and this is controlled largely by the effective positive force of attraction of the cation. This force of attraction (polarizing power) depends on the charge and size of the cation and the efficiency with which its electrons shield (screen) the nuclear charge. A further contributing property may be the response of certain $3d$ transition metal cations to the field of the crystal—so-called crystal-field splitting.

The ionization potential[1] may be used to indicate the effective force of attraction of the cation (see, for example, Ahrens (1953) and Ahrens and Morris (1956)); the greater the energy needed to remove an electron the greater the polarizing power of the resultant cation. In suites of isostructural ionic crystals, those that contain cations of metals with the highest ionization potentials should have the highest refractive indices because the constituent anions should be deformed to the greatest extent. This prediction may be tested by examining groups of isostructural crystals, but because of a number of variables the comparisons should be made as rigorous as possible and in each of the discussions which follow, the anion will be the same, cationic charge will be constant, and the radii of the cations will be similar. Cationic charge distribution is another factor: whereas the charge distribution on 8- and 18-electron cations is probably spherical, that on the transition cations may be different and accordingly transition cations are omitted from the first comparisons.

For our purpose, an ionic compound is taken to mean one in which the ionic radius ratio rules are obeyed: this is not meant to imply that the bonds are regarded as purely ionic.

Refractive indices are usually either from Winchell (1931) or Winchell (1951).

[1] The energy required to remove an electron from an atom or ion.

Isostructural ionic compounds involving 8- and 18-electron cations: Al^{3+} *and* Ga^{3+}; Si^{4+} *and* Ge^{4+}; Ca^{2+} *and* Cd^{2+}; Mg^{2+} *and* Zn^{2+}.

The α refractive indices of the Ga and Ge substituted felspars (Goldsmith, 1950) are: $KAlSi_3O_8$, α 1·518; $KGaSi_3O_8$, α 1·533; $KAlGe_3O_8$, α 1·595; $KGaGe_3O_8$, α 1·615. Elevation of refractive indices by replacement of Al^{3+} and Si^{4+} by Ga^{3+} and Ge^{4+} respectively accords with prediction. The third ionization potentials of Al and Ga are 28·5 and 30·7 volts respectively, and the fourth ionization potentials of Si and Ge are 45·1 and 45·7 volts respectively. In each pair, the force of attraction of the 18-electron cation is evidently greater than that of the 8-electron cation and should cause greater polarization of the anion. The example is quite a good one as radii are similar; Si^{4+} = 0·42 Å, Ge^{4+} = 0·47 Å.; Al^{3+} =0·51 Å., and Ga^{3+} = 0·57 Å.

CaF_2 and CdF_2. The radii of the two cations, Ca^{2+} and Cd^{2+}, are very similar, namely 1·01 and 0·97 Å. Their second ionization potentials (11·9 and 16·9 volts respectively) differ quite considerably (5 volts) and large refractive index differences are anticipated. Unfortunately structurally ionic compounds of cadmium are rare and few comparisons are possible. The pair, CaF_2–CdF_2, each having the 8:4 fluorite structure, is one good example. Goldschmidt (1926) observed that CaF_2 and CdF_2 were completely miscible and that refractive index varied regularly with composition; for CaF_2, n = 1·43 and for CdF_2, n = 1·56. The difference is quite large and accords with theory. The refractive index difference would probably be much larger if the anion were easily polarized.[1]

In the isostructural pair CaO and CdO (both NaCl-type), the respective refractive indices (average for various wavelengths) are 1·84 and 2·49; the difference is very large.

Mg and Zn compounds. The structures of many zinc compounds are not ionic but where comparisons can be made, the refractive indices of the zinc compounds are greater than those of magnesium. This accords with theory; for Zn, I_2 = 17·9 volts and for Mg, I_2 = 15·0 volts (Zn^{2+} = 0·69 Å. and Mg^{2+} = 0·65 Å.). Further discussion on the Mg–Zn relationship is deferred to a later section which compares variation of refractive indices in isostructural compounds involving a variety of medium-sized cations.

[1] F^- is the least polarizable of all anions and this appears to account for the fact that the refractive indices of fluorides are often conspicuously low; compare fluor- and hydroxy-apatites, for example.

Isostructural ionic compounds involving some transition element cations.

Refractive index comparisons between compounds of the pairs of Group IV, V, and VI elements, Zr–Hf, Nb–Ta, and Mo–W, respectively, are particularly satisfactory because for each pair the respective cationic radii are virtually the same and electron configurations are very similar.

In the pair Zr and Hf (radius of $Zr^{4+} = Hf^{4+} = 0{\cdot}79$ Å.), the fourth ionization potentials are ~34 and ~31 volts, respectively. The refractive indices of Zr and Hf compounds are therefore predicted to be very similar, with those of Zr slightly greater than those of Hf. In the isometric compounds $(NH_4)_3ZrF_7$ and $(NH_4)_3HfF_7$, the respective refractive indices are 1·433 and 1·426, which accords with theory. Zirconium and hafnium form tetragonal oxyhalides; $ZrOCl_2.8H_2O$ is uniaxial positive ($\omega = 1{\cdot}552$, $\epsilon = 1{\cdot}563$) whereas $HfOCl_2.8H_2O$ is uniaxial negative ($\omega = 1{\cdot}557, \epsilon = 1{\cdot}543$). In this example the comparison is not so clear: the refractive indices are closely similar as we expect and if either the average or $\sqrt[3]{\omega^2\epsilon}$ is compared, the value for the Zr compound is slightly greater, which is in accordance with theory.

For the pair Nb^{5+} and Ta^{5+} (radius = 0·69 Å.) the fifth ionization potentials are ~50 and ~45 volts respectively. A difference of about 5 volts for quintuply charged cations is comparatively small, and accordingly we predict that the refractive indices of isostructural compounds of niobium and tantalum will be similar but that those of niobium will be slightly greater. The refractive indices of stibiocolumbite and stibiotantalite support this prediction:

$SbNbO_4$	α 2·42	β 2·44	γ 2·46
$SbTaO_4$	α 2·345	β 2·383	γ 2·452.

In tantalite and columbite $(Fe,Mn)(Nb,Ta)_2O_6$ Fe–Mn substitution is a complication. The refractive indices of columbite are, however, greater than those of tantalite.

In the pair Mo^{6+}–W^{6+} (radius = 0·62 Å.), the sixth ionization potentials are ~67 volts and ~60 volts. Refractive indices of the isostructural tetragonal pairs powellite–scheelite and wulfenite–stolzite are as follows:

$CaMoO_4$	ω 1·967	ϵ 1·978	$PbMoO_4$	ω 2·405 ϵ 2·283
$CaWO_4$	ω 1·918	ϵ 1·934	$PbWO_4$	ω 2·27 ϵ 2·19.

The refractive indices of the Mo member in each pair are greater than those of the W member, which is in accordance with theory. We may note also that the refractive indices of the lead minerals are quite distinctly greater than their calcium equivalent ($Pb^{2+} = 1{\cdot}20$ Å.,

Ca^{2+} = 1·01 Å.). This also accords with theory as the second ionization potentials of lead and calcium are 15·0 and 11·9 volts respectively; the comparison is, however, not rigorous, as the difference in radius is quite considerable (0·2 Å.) and a large divalent cation such as Pb^{2+} is itself perhaps quite strongly polarized in the anion field, thereby causing a further elevation of refractive index.

Medium-sized divalent cations of various types.

The largest number of cations of a similar size is the medium-sized group Mg^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, and Zn^{2+}; their radii range from 0·65 Å. (Mg^{2+}) to 0·80 Å. (Mn^{2+} and perhaps Cu^{2+}). It would be desirable to include Pd^{2+} and Pt^{2+} also, but refractive index data on their compounds are not often available. Though the exclusion of other divalent cations from the above series is somewhat arbitrary, we may recall that the fluorides of the cations of this group invariably have the 6:3 rutile structure, whereas that of BeF_2 (Be^{2+} = 0·34 Å.) is 4:2 (cristobalite) and the fluoride structures of many larger cations (Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Cd^{2+}, and Hg^{2+}) are 8:4 (fluorite).

The second ionization potentials in volts of the metals under consideration are Mg 15·0, Mn 15·6, Fe 16·5, Co 17·4, Ni 18·2, Cu 20·2, and Zn 18·0. In two types of compounds it is possible to make a comparison involving each of the seven cations. Consider the trigonal hydrated divalent-quadrivalent hexafluorides, $A^{2+}SiF_6.6H_2O$, where A^{2+} may be Mg, Mn, Fe, Co, Ni, Cu, or Zn. The Mg, Mn, Fe, Co, Ni, and Zn compounds are uniaxial positive whereas the Cu compound is uniaxial negative.

The second ionization potential is related to refractive index in fig. 1. A well-developed regularity is clear and in general the relationship is in accordance with theory outlined so far. The change of sign in the copper compound might reflect some unique property associated with Cu^{2+} and in the example below (see fig. 2) the copper compound again shows a peculiarity. It may be recalled that although coordination about Cu^{2+} can often be regarded as octahedral, four neighbours are usually closer than the other two. The Mg–Fe relationship above holds generally for mafic minerals such as olivine and pyroxene and the higher refractive indices of the Fe-rich component are probably due to greater deformation of O^{2-} in the field of Fe^{2+}.

A large number of compounds of the type $A_2^+B^{2+}(SO_4)_2.6H_2O$ are known in which A^+ is a large singly charged cation (K^+, Rb^+, Cs^+, Tl^+, or NH_4^+) and B^{2+} is a medium-sized divalent cation. The relationship

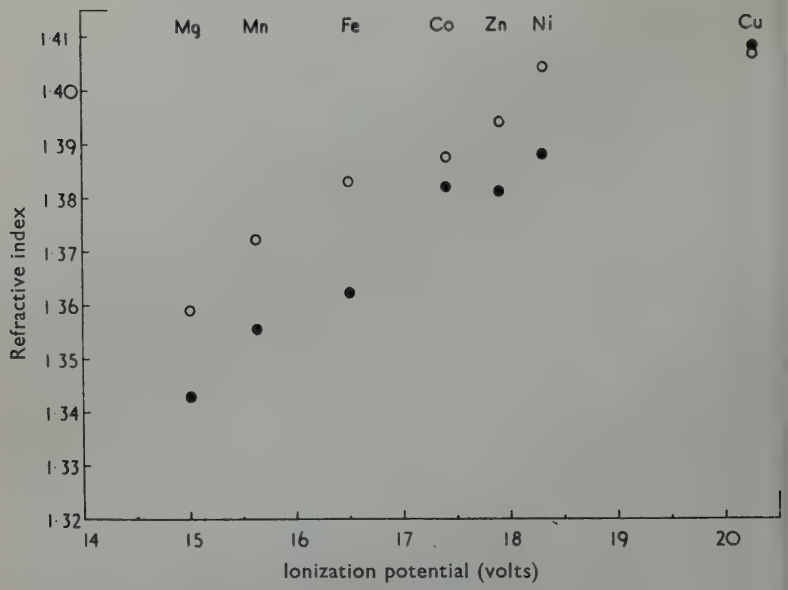

FIG. 1. Variation of refractive indices with second ionization potential of metal in tetragonal crystals of the type $A^{2+}SiF_6.6H_2O$. ● = ω, ○ = ϵ.

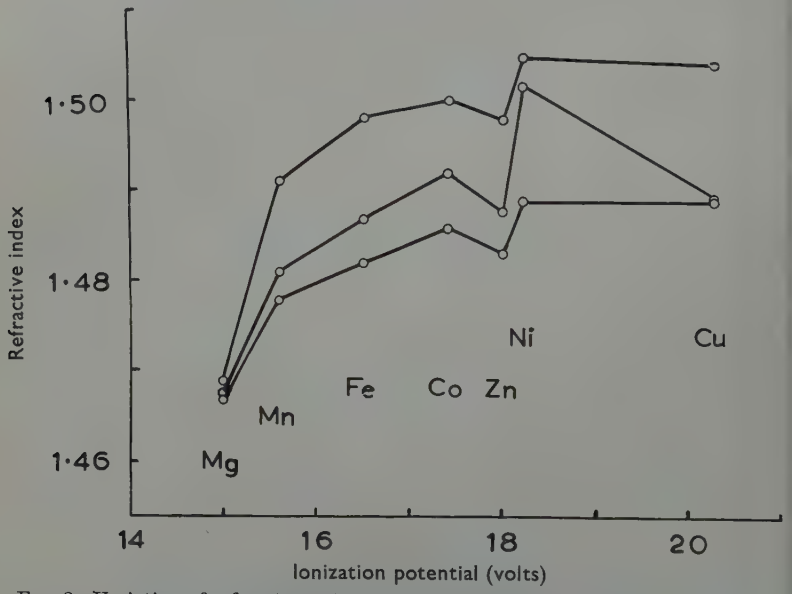

FIG. 2. Variation of refractive indices with second ionization potential of metal in monoclinic sulphates of the type $Rb_2B^{2+}(SO_4)_2.6H_2O$.

between second ionization potential and refractive index shown in fig. 2 refers to the rubidium compounds but holds fairly well for the others as well. The general trend of fig. 1 is again clear in fig. 2, but the regularities are not so well developed and distinct discontinuities appear at zinc. Also, unlike the fluosilicates, the refractive indices of copper rubidium sulphate tend to be less than those of nickel, particularly the β index. In the K, Cs, NH_4, Tl salts, as well as the isomorphous selenates (the Cs selenate excepted), the drop in β index is smaller when passing from the nickel compound to the copper compound.

We may note one difference between the Tutton salts and the fluosilicates that may be important: in the Tutton salts each cation is surrounded by six H_2O's which form an octahedron distorted from the regular shape by being elongated along an axis passing through two opposite water molecules, but having very nearly tetragonal symmetry (Hoffman, 1931; Abragam and Pryce, 1951); magnetic experiments indicate a crystal electric field of tetragonal symmetry. In cobalt fluosilicate (Abragam and Pryce, 1951) and perhaps also in the other fluosilicates, the octahedral group of H_2O molecules is more nearly regular than in the Tutton salts; distortion is in the form of compression along a trigonal axis and the cation is located in a crystal electric field of trigonal symmetry. A refractive index drop at zinc, as above, may be observed also in some other compounds such as the carbonates and simple sulphates, and in fact the relationship $Mg^{2+} < Zn^{2+} < Fe^{2+}$, Co^{2+}, Ni^{2+}, and Cu^{2+} is quite common; thus the refractive index of the compound with an 8-electron cation is lowest, that containing the 18-electron cation comes next, whereas compounds containing 3*d* transition element cations may have the highest refractive indices. Such a relationship holds quite often also for compounds of medium-sized R^{3+} cations: Al^{3+} (8-electron) $< Ga^{3+}$ (18-electron) $< Cr^{3+}$, Fe^{3+}, Co^{3+}, and Rh^{3+} (all transition). In the alums, for example, the relationship is Fe^{3+} (highest) $> Ga^{3+} > Al^{3+}$, and the same relationship holds also for orthoclase where synthetic Fe^{3+} orthoclase has α and γ 1·601 and 1·609, respectively (Gaubert, 1926; see also Coombs, 1954), compared with lower values for Ga and still lower for Al orthoclase (see above). These relationships accord only in part with the magnitudes of the ionization potentials and lack of complete correlation, when a variety of cation types are considered, may be due to the effect of the crystal-field on the transition element cations.

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Heat treatment of metamict euxenites, polymignites, yttrotantalites, samarskites, pyrochlores, and allanites.

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Summary. The standard thermal treatments proposed by Lima-de-Faria have been applied to metamict euxenites, polymignites, yttrotantalites, samarskites, pyrochlores, and allanites. In the case of these metamict niobotantalates a face-centred cubic phase is formed at 700° C., and at 1000° C. a more characteristic phase appears combined with the cubic one. In the case of allanites only a slight formation or strengthening of the original structure of allanite appears at 700° C., and at 1000° C. a cubic phase is formed together with other phases.

STANDARD thermal treatments for metamict minerals were proposed by Lima-de-Faria (1956) to make easier the identification of metamict minerals by X-ray powder photographs. The choice of the conditions for these heat treatments was based on the hypothesis that up to 1000° C. only two crystalline phases, or at the most three, will in general develop on heating. It was also pointed out that in many cases the phase formed at low temperature is cubic, and at 1000° C. a second, more characteristic crystalline phase appears, combined with the first one.

The present paper is intended as a contribution of observational data concerning this problem.

We have applied these standard thermal treatments to a range of metamict niobotantalates: euxenites, polymignites, yttrotantalites, samarskites, and pyrochlores. All these niobotantalates were completely metamict as shown by the powder photographs, which exhibit no lines at all, and for each mineral species at least three samples from different sources were investigated.

On heating the powders in air to 700° C. for 3 hours—the secondary standard thermal treatment—face-centred cubic phases are obtained. For euxenites and polymignites we got a 5·07 Å., for yttrotantalites a 10·28 Å., for samarskites a 5·16 Å., and for pyrochlores a 10·38 Å. (tables I and II). Following Orcel (1956) we think that these cubic phases are probably oxides of one or two of the main elements of the minerals. The cell dimension of ZrO_2 is a 5·07 Å. (Duwez and Odell, 1950), and, since

TABLE I. X-ray diffraction powder data for polymignite from Frederiksvarn, Norway, and for euxenite from south Norway, heated in air to 700° C. for 3 hours and heated in air to 1000° C. for 1 hour; Fe-$K\alpha$ radiation; *I* estimated by eye. Also for a euxenite from Ontario, Canada, heated to 1000° C. for 100 hours; Cu-$K\alpha$ radiation (Arnott, 1950). *b*, broad; *vb*, very broad. The indices refer to a cubic cell with *a* about 5·07 Å.

	Polymignite, Frederiksvarn, Norway.				Euxenite, south Norway.				Euxenite, Ontario. (Arnott, 1950)	
	700°, 3 hr.		1000°, 1 hr.		700°, 3 hr.		1000°, 1 hr.		1000°, 100 hr.	
hkl.	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*
									7·30	1
									5·16	2
							3·62	4	3·66	3
							3·35	1	3·36	2
							3·26	1		
							2·97	10	2·98	10
111	*2·92*	10	*2·94*	10	*2·92*	10	*2·93*	4	—	
			2·81	3						
							2·77	3	2·77	2
									2·61	¼
							2·58	2	2·58	2
002	*2·53*	4	*2·52*	4	*2·53*	4	*2·53*	2	2·54	½
							2·42	1	2·43	3
							2·30	1	2·30	1
									2·252	¼
							2·20	1	2·199	1
									2·182	1
							2·11	2	2·106	2
									2·071	¼
									2·025	½
							1·97	1	1·970	½
									1·935	1
							1·89	4	1·889	2
							1·83	5	1·823	4
022	*1·79*	7	*1·82*	8	*1·79*	7*b*	*1·80*	6	—	
							1·77	4	1·769	3
			1·75	5						
							1·72	5	1·723	4
									1·679	½
							1·64	5	1·635	3
									1·605	1
									1·583	½
							1·56	3	1·560	1
113	*1·53*	7	*1·55*	5	*1·53*	7*b*	*1·54*	6	—	
			1·53	5						
									1·522	¼
									1·501	¼
							1·49	4	1·487	4

TABLE I (*cont.*).

	Polymignite, Frederiksvarn, Norway.				Euxenite, south Norway.				Euxenite, Ontario. (Arnott, 1950)
	700°, 3 hr.		1000°, 1 hr.		700°, 3 hr.		1000°, 1 hr.		1000°, 100 hr.
hkl.	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å. *I.*
222	*1·46*	1*b*	*1·48*	2*b*	*1·46*	1*vb*	*1·46*	1	1·457 1
							1·44	3	1·436 2
									1·400 ½
									1·391 ½
									1·359 1
							1·340	1	1·336 2
									1·311 1
							1·290	1	1·292 1
004	*1·267*	1*b*			*1·269*	1*vb*	*1·280*	2	—
									1·273 ½
			1·260	1					
									1·256 ½
									1·241 ½
							1·225	1	1·222 2
									1·216 1
									1·203 1
							1·185	1	1·182 2
133	*1·167*	3*b*	*1·179*	5	*1·164*	2*vb*	*1·174*	5	1·173 2
							1·159	2*b*	1·156 3
024	*1·133*	3*b*	*1·149*	2*b*	*1·135*	2*vb*	*1·145*	4	1·143 ½
							1·118	1	1·119 ½
			1·115	1					
									1·110 1
							1·103	1	1·100 1
									1·091 ½
							1·083	2*b*	1·080 2
							1·057	1*vb*	1·057 1
			1·050	2					
224	*1·034*	2*vb*	*1·038*	3	*1·034*	2*vb*	*1·045*	3*b*	1·046 1
							1·034	1*vb*	1·030 ½
							1·020	3*vb*	1·024 2
									1·015 1
									1·008 ½
							1·001	1*vb*	0·996 1
115 } 333 }			*0·985*	2*vb*			*0·985*	3*vb*	0·986

polymignite generally has a high Zr content, the cubic phase observed for polymignite might be ZrO_2.

These minerals were heated in powder rather than in fragment form for the sake of better standardization. In fact, if air oxidation does occur it can be complete when powder is used, whilst it may be confined to the outer portion in the case of fragments, consequently leading to differences in results.

On heating the powders in air to 1000° C. for 1 hour—the basic standard thermal treatment—new lines appear in addition to the lines of the cubic phase (tables I and II). These results are similar to those obtained with thorite (Pabst, 1952) who observed that ThO_2 develops first, followed by tetragonal and monoclinic forms of $ThSiO_4$. Attempts to identify euxenite or polymignite by powder photographs from heat treatment at 700° C. alone would lead to ambiguous results (see table I), whereas by heating at 1000° C. the new lines observed are different, and accurate conclusions can be drawn. One of the samples of pyrochlore (from Frederiksvarn, Norway) and a microlite from Virginia, U.S.A., give at 1000° C. only the cubic phase.

X-ray diffraction powder data for samarskites are not included in this paper, because the standard thermal treatments of samarskites lead to results closely similar to those obtained by Lima-de-Faria (1956), heating at 600° C. for 5 hours and 1000° C. for $1\frac{1}{2}$ hours.

In the case of euxenite, Arnott (1950) observed differences on the powder photographs from samples heated to 400° C., 800° C., and 1000° C., and ascribed these differences to an incomplete recrystallization of an orthorhombic phase. On heating euxenite to 1200° C., Berman (1955) also obtained a few strong lines that could not be indexed on the basis of the orthorhombic phase pointed out by Arnott. In fact two phases are formed at 1000° C., one cubic and one orthorhombic, in varying proportions. The powder pattern selected by Arnott for indexing corresponds to heating in air to 1000° C. for 100 hours, which prolonged heat treatment probably made the cubic phase virtually vanish, so that only the orthorhombic phase was obtained. This can be seen in table I: the strong lines of the cubic phase are missing on Arnott's diffraction powder data. Another euxenite, namely a tanteuxenite, studied by Arnott (1950), gives a cubic pattern with a 5·10 Å., which is similar to the author's own results.

We have also applied these heat treatments to several metamict allanites.

X-ray powder patterns were taken of nine unheated allanites from

different localities for a preliminary assessment of the state of the samples. Powders of five of these allanites, ranging from completely to slightly metamict, were heated in air to 700° C. for 3 hours, and only a slight formation of the original structure, or strengthening of this original structure in the case of partially metamict samples, was observed.

The application of the basic standard thermal treatment (1000° C. for 1 hour in air) to the nine allanites yielded very good and similar powder photographs, which seem to be a combination of lines from a cubic phase, a few from the original structure, and a few more from one other phase. The plane spacings printed in italics (table II) fit well to a face-centred cubic phase with a 5·44 Å. Slight differences observed on

TABLE II. X-ray diffraction powder data for yttrotantalite from Ytterby, Sweden, pyrochlore from Langsundfjord, Norway, and allanite from Greenland, heated in air to 700° C. for 3 hours and heated in air to 1000° C. for 1 hour. Cu-$K\alpha$ radiation for yttrotantalite and allanite, Fe-$K\alpha$ radiation for pyrochlore; *I* estimated by eye. The indices refer to the cubic unit cells mentioned in the text.

Yttrotantalite, Ytterby, Sweden.					Pyrochlore, Langsundfjord, Norway.					Allanite, Greenland.				
700° C., 3 hr.			1000° C., 1 hr.		700° C., 3 hr.			1000° C., 1 hr.		700° C., 3 hr.		1000° C., 1 hr.		
hkl.	*d*, Å.	*I.*	*d*, Å.	*I.*	*hkl.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*d*, Å.	*I.*	*hkl.*	*d*, Å.	*I.*
111	*5·82*	2	*5·87*	2				3·87	5				4·0	1
			4·67	2	113	*3·10*	1	*3·12*	1				3·67	1
			3·59	1	222	*2·98*	10	*2·98*	10				3·18	10
113	*3·08*	1	*3·09*	2				2·74	7			111	*3·11*	8
			3·01	4	004	*2·59*	3	*2·59*	4	2·93	1*vb*		2·93	3
222	*2·93*	10	*2·95*	10	115 333	*2·01*	1	*1·99*	1			002	*2·71*	5
			2·90	2				1·94	4				2·53	2*b*
			2·74	1*b*	044	*1·83*	7	*1·83*	10	2·15	1*vb*		2·15	1*b*
004	*2·55*	6	*2·56*	6				1·74	3				1·98	1
			2·44	1				1·59	5			022	*1·92*	9
			2·20	1	226	*1·56*	7	*1·56*	10	1·89	1*vb*			
			2·16	2	444	*1·49*	3	*1·50*	3				1·86	3
			2·06	1				1·376	3				1·77	2
115 333	*1·98*	1	*1·98*	1	355 137	*1·348*	1*vb*	*1·358*	1	1·64	1*vb*	113	*1·64*	9
			1·90	4*b*	008	*1·294*	2*vb*	*1·296*	4			222	*1·57*	2
			1·85	1	266	*1·189*	4*b*	*1·190*	7				1·52	2
044	*1·81*	8	*1·81*	9	048	*1·153*	4*b*	*1·160*	7				1·46	2*b*
			1·74	4				1·125	1*b*			004	*1·361*	4
			1·70	2				1·080	1*b*			133	*1·247*	5
			1·58	1*b*	448	*1·060*	4*b*	*1·060*	7*b*			024	*1·214*	5
226	*1·55*	8	*1·55*	9				1·041	7*b*			224	*1·110*	4
												115 333	*1·047*	4
444	*1·48*	3	*1·49*	4	666	*1·000*	4*b*	*1·000*	7*vb*					
			1·46	3								044	*0·963*	2
355 137			*1·344*	1*b*								135	*0·920*	4
												006 244		2
008	*1·283*	2*b*	*1·288*	4								026		4
266	*1·179*	4*b*	*1·183*	6								335		2
048	*1·149*	4*b*	*1·152*	6										
448	*1·049*	3*b*	*1·053*	5										
666	*0·989*	3*b*	*0·994*	5										

the powder patterns might be ascribed to varying proportions of the phases.

Berman (1955) pointed out that as allanite melts or decomposes at a relatively low temperature it would not be advisable to heat allanite above the temperature of 850° C., if reliable X-ray patterns corresponding to simple recrystallization are to be obtained. For identification purposes what seems to be important is to obtain a characteristic diffraction pattern for a mineral species, and not necessarily from its original structure. Consequently, melting during the heat treatment will not be any disadvantage provided that a good crystallization is obtained after cooling. Ueda and Korekawa (1955) showed that some allanites melt at 1400° C. and that good diffraction patterns could be obtained after cooling.

For comparison with the results obtained by Berman we have also taken X-ray powder photographs of five of these allanites heated in air to 800° C. for $\frac{1}{2}$ hour. The results obtained are similar to those at 700° C., and do not include any powder patterns suitable for identification purposes.

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On the unit cell of calcium potassium sulphate hydrate: synthetic and natural syngenite.

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Summary. The space group and unit cell of natural syngenite have been redetermined. X-ray powder photographs of natural syngenite and synthetic $CaSO_4.K_2SO_4.H_2O$ were found to be practically identical. Optical and d.t.a. data are also given.

A MATERIAL causing a dark stain to appear on the surface of a gypsum building plaster could not be satisfactorily identified using the data available in the A.S.T.M. Index (1955). Other evidence suggested that the material was produced by the interaction of dissolved potassium sulphate with the gypsum. An attempt to form the material under controlled conditions was successful, and the product proved to be syngenite. Since the two published reports on the unit cell of the mineral showed significant differences, a redetermination of the unit cell was carried out on the synthetic material and also on natural crystals.

The synthetic mineral was prepared as follows: a cake of gypsum plaster, about 5 mm. thick, was partly immersed in a shallow dish of K_2SO_4 solution at room temperature; after two weeks the slab was taken out and dried in the air. When the crusty surface was removed, the soft white core was found to be homogeneous and was identified as syngenite.

Chemical analysis by Mrs. A. J. Green gave: CaO 17·1, K_2O 28·1 (by difference), SO_3 48·6, insoluble residue 0·6 (probably gypsum and quartz, as shown by X-ray analysis of the residue), loss at 700° C. 5·6 %. This can be represented by formula $CaSO_4.0{\cdot}98K_2SO_4.1{\cdot}02H_2O$. Under a microscope the crystals appear as birefringent needles, showing straight extinction, positive elongation, $\alpha = 1{\cdot}500$, $\gamma = 1{\cdot}518$, in agreement with data for natural syngenite. Specific gravity 2·56–2·58.

Differential thermal analysis shows a larger endothermic peak at 285° C., smaller peaks at 440° and 560° C., and a medium peak at 880° C. Bodaleva and Lepeshkov (1956) recorded peaks at 265°, 430°, 560°, 880°, and 950° C.

Natural syngenite from Glückauf, Sondershausen, Thuringia (B.M. 1913,368), was kindly supplied by Dr. G. F. Claringbull.

X-ray investigation. The unit cell and space group of syngenite have been determined by single crystal methods by Laszkiewicz (1936) on a sample from Kalusz, and by Kurylenko (1954) on a sample of unknown origin; an abstract only of the latter paper has been published. Both found syngenite to be monoclinic, space group $P2_1/m$–C_{2h}^2 ($0k0$ reflections appear only when k is even), but the axial lengths differ significantly. Their results, together with those of the present investigation, are given in table I.

TABLE I. The unit cell of syngenite.

Author.	Sample.	*a*.	*b*.	*c*.	*β*.
Laszkiewicz	Single crystal	9·72	7·16	6·21 Å.*	104°
Kurylenko	Single crystal	9·55	7·13	6·00 Å.*	105°
Aruja	Synthetic, powder	9·775	7·156	6·251 Å.	104·0°
Aruja	Natural, powder	9·771	7·146	6·251 Å.	104·02°
Aruja	Natural, single crystal	9·774	7·156	6·249 Å.	133·95°

Axial ratios: X-ray method: synthetic, powder .. 1·3660:1:0·8735
Optical goniometry (Dana, 7th edn) .. 1·3691:1:0·8747

* Converted into Å. units from kX.

The present work confirms the space group found by earlier workers, but the axial lengths are found to be closer to those given by Laszkiewicz.

Oscillation and rotation photographs of single crystals of the natural mineral were taken about the *b*- and *c*-axes in a 6-cm. diameter camera, with filtered Cu-$K\alpha$ radiation. Powder photographs were taken in an 18-cm. diameter Debye-Scherrer camera (Co-radiation) as well as in a focusing camera of slightly higher resolution (Cu-radiation). The powder patterns of the synthetic and natural syngenite are practically identical. Only the difference of 0·01 Å. in the length of the *b*-axis, shown in table I, seems to exceed the limit of probable error.

The powder data for both natural and synthetic syngenite are reproduced in table II. This records substantially more lines than the card in the A.S.T.M. index (1955). Comparison with the table of $\sin^2\theta$ values given by Bodaleva and Lepeshkov (1956) is made difficult because the X-ray wavelength they used is not stated. Assuming two molecules of $K_2Ca(SO_4)_2.H_2O$ in the unit cell, the calculated density is 2·570 g./c.cm., which compares well with the measured density of the synthetic mineral, 2·56–2·58. For natural syngenite the figures are $D_{calc.} = 2{\cdot}575$ and $D_{obs.} = 2{\cdot}579$ (Dana, 7th edn).

TABLE II. X-ray powder data for syngenite. Camera diameter 18·4 cm., Co-$K\alpha$ radiation (λ 1·7902 Å.). The three strongest lines are italicized. Natural syngenite from Glückauf, Sondershausen, Thuringia (B.M. 1913,368). Synthetic syngenite: calcium sulphate di-hydrate slab soaked in K_2SO_4 solution. Indices calculated for a monoclinic cell with a 9·775, b 7·156, c 6·251 Å., β 104·0°; the relative importance of jointly contributing planes has not been assessed. Intensities for the natural mineral were obtained by a calibrated strip, and can be taken to apply to the synthetic material. *b*, broad line, *D*, doublet, resolved on focusing camera; n.m., not measured because of weakness. $\Delta = 4\sin^2\theta_{obs.} - 4\sin^2\theta_{calc.}$

Natural.		Synthetic.			
d.	*I.*	*d.*	$4\sin^2\theta_{obs.}$	*hkl.*	$\Delta.10^4$
9·514	*62*	*9·522*	0·0353	100	−3
5·716	56	5·712	0·0982	110	0
4·748	9	4·743	0·1425	200	0
4·630	38	4·626	0·1499	011	+2
				10$\bar{1}$	+2
4·499	19	4·501	0·1582	11$\bar{1}$	−2
3·951	8	3·960	0·2046	210	−5
3·884	15	3·889	0·2123	111	0
3·571	19	3·573	0·2508	020	+4
3·348	22	3·350	0·2681	201	+26
				120	+1
3·157	*75*	*3·161*	0·3206	300	0
3·110	6	3·114	0·3300	30$\bar{1}$	+31
				10$\bar{2}$	−2
				12$\bar{1}$	+21
3·035	34	3·035	0·3482	211	+21
				002	−3
2·953	1	not obs.			
2·896	12	2·896	0·3832	310	0
				20$\bar{2}$	0
2·857	*100*	*2·860*	0·3922	11$\bar{2}$	−6
				220	−7
2·823	22	2·827	0·4013	121	+12
2·789	22	2·791	0·4111	012	0
2·740	38	2·741	0·4264	22$\bar{1}$	+3
2·702	5	2·705	0·4378	102	−2
n.m.	1	2·680	0·4460	21$\bar{2}$	+2
2·511	25	2·514	0·5071	30$\bar{2}$	−3
2·447	4	2·449	0·5342	221	+3
2·408	5	2·412	0·5512	40$\bar{1}$	+19
				31$\bar{1}$	0
				31$\bar{2}$	+8
2·373	5	2·369	0·5708	400	+8
				320	−2
				32$\bar{1}$	+11
2·353	18	2·353	0·5784	12$\bar{2}$	−22
				202	−4
2·313	10	2·314	0·5984	022	−5
				130	−5
2·287	1	2·289	0·6116	41$\bar{1}$	−3
2·247	1	2·249	0·6337	410	+9
				22$\bar{2}$	+1
n.m.	1	2·219	0·6512	031	+8
2·200	2	2·200	0·6625	13$\bar{1}$	+34
				212	+11
n.m.	1	2·132	0·7049	230	−7
				40$\bar{2}$	+20
				23$\bar{1}$	+1
2·083	19	2·082	0·7391	321	+1
				103	+2
2·045	22	2·047	0·7646	40$\bar{1}$	−3
				20$\bar{3}$	−3
				41$\bar{2}$	−9
1·999	6	2·001	0·7999	42$\bar{1}$	+2
				113	−16
				41$\bar{1}$	+30
1·963	18	1·965	0·8305	21$\bar{3}$	+30
				302	−3
				013	+15
1·943	15*D*	1·945	0·8482	231	+14
				222	−10
1·901	5	1·904	0·8839	330	0
				500	+41
1·892	10	1·892	0·8947	312	+13
				13$\bar{2}$	+12
1·872	8	1·875	0·9118	032	0
1·836	4	1·839	0·9478	23$\bar{2}$	+13
n.m.	1	1·819	0·9685	113	+53
				50$\bar{2}$	−11
1·787	22	1·788	1·0027	13$\bar{2}$	+14
				040	+13
n.m.	1	1·777	1·0155	421	+2
				22$\bar{3}$	+2
				40$\bar{3}$	+32
1·759	2	1·761	1·0339	51$\bar{2}$	+17
				023	−6
n.m.	1	1·745	1·0520	331	+1
1·728	2	1·730	1·0702	33$\bar{2}$	−5
n.m.	1	1·712	1·0933		
n.m.	1	1·696	1·1137		
n.m.	1	1·676	1·1411		
n.m.	1	1·669	1·1499		
n.m.	1	1·661	1·1617		
n.m.	1	1·591	1·2654		
n.m.	1	1·581	1·2826		
n.m.	1	1·567	1·3050		
1·556	8*b*	1·556	1·3248		
1·530	4	1·532	1·3664		
1·483	2	1·484	1·4566		
n.m.	2*b*	1·450	1·5253		
n.m.	1	1·428	1·5713		
n.m.	1	1·417	1·5957		
n.m.	1	1·397	1·6415		
1·369	5*b*	1·370	1·7068		
n.m.	2	1·351	1·7572		
n.m.	1	1·340	1·7864		
n.m.	1	1·330	1·8129		
1·321	6*b*	1·321	1·8351		
&c.		&c.			

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Minium from Broken Hill, New South Wales.

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[Read 27 March 1958.]

Summary. Minium occurs at Broken Hill, New South Wales, as pseudomorphs after cerussite, formed during fires in the mine. It is tetragonal with $a = 8{\cdot}824$ Å. and $c = 6{\cdot}564$ Å.; sp. gr. $8{\cdot}2 \pm 0{\cdot}2$. The Broken Hill minium appears identical in physical properties with synthetic Pb_3O_4 described by other workers.

MINIUM (Pb_3O_4) occurs extensively in the upper workings of the central portion of the Broken Hill mining field, as brilliant scarlet pseudomorphs after cerussite or partially replacing the cerussite. Early descriptions of the mineralogy of Broken Hill do not mention the occurrence of minium. However, after large underground fires in the early part of this century, minium was found extensively in the fire zones. It appears to have formed only from lead carbonate, as there is no evidence that either the sulphate or sulphide were converted to Pb_3O_4. It seems certain that the minium at Broken Hill was formed by the oxidation of cerussite through the agency of mine fires. If any minium formed by other agencies is present, it must be exceedingly rare, because it has not, to our knowledge, been recorded in previous mineralogical studies.

Minium forms perfect pseudomorphs after cerussite, even to the extent of preserving the cerussite cleavages, and in this case has the appearance of a true single crystal. However, rotation X-ray photographs of the pseudomorphs about the axes of the original cerussite crystal give normal powder patterns. This indicates that the minium grains replacing the cerussite are randomly oriented, and further, since the diffraction lines are of even intensity throughout, that the grain size of the minium is extremely small.

Partial replacement of the cerussite by minium is common (fig. 1). We could not detect any tendency towards preferential replacement along specific crystal directions. Rather, the variations in the extent of replacement appear to be related to the channel-ways in the rock through which gases could enter or escape. Thus, crystals growing in a vugh are more extensively replaced on those portions projecting freely into the

vugh, while at the base of the crystals, where they are extensively intergrown, replacement is much less.

Chemical analysis of a specimen from the old Central Mine (Geol. Dept. Univ. of Adelaide No. 1193) gave 89·94 % Pb, 0·2 % Fe, $< 0{\cdot}1$ % Zn; CO_2 absent. This is very close to the theoretical 90·67 % Pb for Pb_3O_4; although O was not specifically determined, it appears that the specimen analysed is very close to stoichiometric proportions.

FIG. 1. Minium (appears dark grey) pseudomorphically replacing cerussite (light grey). The crystal is 3 mm. in length.

The specific gravity was determined on the Berman Torsion Balance, using toluene as the immersion liquid. Ten measurements gave a value of $8{\cdot}2 \pm 0{\cdot}2$.

Excellent X-ray powder diffraction photographs were obtained. The measurements and indices assigned to each diffraction line are recorded in table I. Certain lines are quite diffuse; this feature has previously been noted by Byström and Westgren (1943) on synthetic material, and is a property of the substance rather than a grain-size effect, since most lines are sharp and clearly resolved.

Darbyshire (1932) reported on the differentiation of the different oxides of lead by X-ray powder diffraction. Unfortunately, he did not record measurements for Pb_3O_4, but as far as we can tell by comparison with his published photograph of the pattern for Pb_3O_4, it is identical with ours. Byström and Westgren (1943) published powder diffraction data for synthetic Pb_3O_4. Our measurements agree well with theirs, although

TABLE I. X-ray powder diffraction data for minium. Co-$K\alpha$ radiation, λ 1·7902 Å. Intensities visually estimated. Average of 3 films. 114·59 mm. diameter camera.

hkl.	*d*, Å.	*I.*	*hkl.*	*d*, Å.	*I.*
110	6·22	m	611	1·414	m
211	3·38	s	532	1·373	w
002	3·29	vw	621	1·365	vw
220	3·114	m	541	1·347	w
112	2·905	s	523	1·311	w(b)
310	2·787	s(b)	622	1·283	w(b)
202	2·633	m	424	1·262	w
320	2·446	w	710, 550	1·245	m
321	2·291	w	712, 552	1·166	m
222	2·258	w	325	1·157	w(b)
400	2·205	vvw	642	1·146	m
330	2·078	vw	444	1·130	m
411	2·033	w(b)	534	1·112	w
420	1·968	m(b)	006	1·094	w(b)
213	1·913	m	116	1·078	w
402	1·829	m(b)	206	1·061	vw(b)
332	1·755	s	742, 812	1·038	m
431, 501	1·702	vvw	525	1·025	w(b)
004	1·640	w	653	1·003	w
521	1·587	w(b)	554, 714	0·9921	w
440	1·558	m	752	0·9786	w(b)
413	1·531	w(b)	336	0·9683	m
530	1·512	w	761	0·9466	w(b)
600	1·470	w(b)	516	0·9252	w(b)
610	1·453	w	217	0·9123	w

they have recorded several weak lines that do not appear on our films, and similarly, we have recorded several that do not appear on theirs. This discrepancy is more probably due to the restrictions of the powder method than to any real difference in the substances, since in both cases all the diffraction lines can be indexed on the same unit cell.

All the diffraction lines can be satisfactorily indexed on a tetragonal cell with a 8·824 Å. and c 6·564 Å. These dimensions agree well with those of Byström and Westgren (1943), and Byström (1945), but are somewhat smaller than those of Straumanis (1942) and Gross (1943); after conversion of kX units to Å. we have:

	a	c	c/a
Straumanis (1942)	8·893 Å.	6·52 Å.	0·733
Byström and Westgren (1943)	8·82	6·57	0·745
Gross (1943)	8·88	6·67	0·751
Byström (1945)	8·806	6·564	0·745
Present work	8·824	6·564	0·741

Gross (1943) determined the space group of synthetic Pb_3O_4 as $P\bar{4}b2$, with a pseudosymmetry of $P4/mbc$. Byström (1945) obtained better crystals than Gross and established the true symmetry as $P4/mbc$.

Lacking adequate material we cannot confirm this, but there seems no reason to doubt that the Broken Hill minium is in every way identical with the synthetic material described by previous workers.

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Twenty-first list of new mineral names.

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PREVIOUS lists (nos. 1–20), given triennially (1897–1955) at the ends of vols. 11–30 of this Magazine, contain 3153 mineral names that have appeared in the world's literature since the publication in 1892 of the sixth edition of Dana's 'System of Mineralogy'. The present list adds a further crop of 210.

For international usage it is of prime importance that the original spelling of a name should be retained as nearly as possible.[1] Unfortunately, however, there are still national tendencies to modify the spelling of names with the mistaken idea of indicating the 'correct' pronunciation, whether that of the original language or of one or other dialects in some other language. For example, the old and well-known name Childrenite has recently been altered in German to Tschildrenit, and is so lost in an alphabetical index.

The Latin alphabet is used in most European languages, but often with a variety of diacritical marks. For example, Jarošite (15th List) is not the same mineral as Jarosite. [š (Czech, Croatian) = sh (English), ch (French), sch (German), sz (Polish), ş (Romanian, Turkish), s (Magyar).][2] For languages with other alphabets there are further difficulties. For example, Шубниковит (Russ.) = Shubnikovite (Eng.) = Choubnikovite (Fr.) = Schubnikowit (Germ.), with scatter in an alphabetical index. In the case of double transliteration errors arise and there may be startling metamorphic changes. For example:

Halloysite → Галлуазит → Galluasite[3] → Gaylussite (?).
Hibschite → Гибшит → Gibshite → Gibbsite.[4]
Humite → Гумит → Gumite → Gummite (?).
Whewellite → Вевеллит → Vevellite → Wavellite (?).

[1] L. J. Spencer, International agreement in mineralogical and crystallographical nomenclature. Min. Mag., 1925, vol. 20, pp. 353–363; Some mineral names. Amer. Min., 1937, vol. 22, pp. 682–685.

[2] Alphabets of foreign languages. Roy. Geogr. Soc., Techn. Ser. no. 2, reprint of 2nd edition with corrections, London, 1951.

[3] Brit. [Chem.] Abstr., 1950, AI, col. 99.

[4] Journ. Chem. Soc. London, 1910, Aii, p. 137.

Abernathyite. M. E. Thompson, B. Ingram, and E. B. Gross, 1956. Amer. Min., vol. 41, p. 82. $K(UO_2)AsO_4.4H_2O$, tetragonal, meta-autunite group. Small yellow crystals from Temple Mts., Utah. Named after Mr. Jess Abernathy, who found the material. [M.A. **13**–86.]

Absite. A. W. G. Whittle, 1954. Mining Rev. South Australia Dept. Mines, no. 97 (for 1952), p. 99 (absite), p. 142 (absite, thorium brannerite). Variety of brannerite (9th List) containing ThO_2 12·81 %. $2UO_2.ThO_2.7TiO_2.5H_2O$. From Crockers Well, South Australia. Deposit located with air-borne scintillometer, hence the name. [M.A. **13**–87.]

Agathocopalite. J. Paclt, 1953. Tschermaks Min. Petr. Mitt., ser. 3, vol. 3, p. 342. A recent resin (copalite) containing agathic acid ($C_{20}H_{30}O_4$), from the conifer *Agathis*. [M.A. **12**–306.]

Allokite. B. J. S. Collins, 1955. Diss. Univ. Illinois, vol. 15, no. 11, p. 2163. Composite name for a clay mineral with layer structure intermediate between allophane and kaolinite.

Alouchtite. Bull. Soc. Franç. Min. Crist., 1956, vol. 79. p. 339. French spelling of alushtite from Russian алуштитъ (10th List). A mixed clay mineral.

Alterite. Tj. H. van Andel, 1950. Rhine sediments, Diss. Groningen, p. 45 (alterites), p. 46 (epidote-alterite, &c.). D. Carroll, Amer. Min., 1957, vol. 42, p. 110. A loose term for weathered (altered) grains of heavy minerals, usually not identifiable from their optical characters.

Alumoferroascharite. D. P. Serdyuchenko, 1956. Mém. Soc. Russ. Min., vol. 85, p. 292 (алюмоферроашарит). Variety of ascharite containing Al_2O_3 6·47, FeO 8·79, Fe_2O_3 4·30 %. Formula $(Mg,Fe)(B,Al)O_2.OH$. [M.A. **13**–522 (alumoferroasharite).]

Alumolimonite. G. A. Bilibin, 1928. A. K. Boldyrev, Kurs Opisat. min., Leningrad, 1928, no. 2, p. 97 (алюмолимонит). S. I. Beneslavsky, Doklady Acad. Sci. USSR, 1957, vol. 113, p. 1130. Mixture of aluminium and iron hydroxides. [M.A. **13**–520.]

Ammersooite. H. W. van der Marel, 1954. Soil Science, vol. 78, pp. 172, 176 (ammersooite). A variety of illite capable of fixing potassium in Dutch soils. Named from the potash experimental field near Ammerzoden (locally called Ammersooien), Gelderland, Holland.

Andreattite. R. C. Mackenzie, 1954. Anal. Edafol. y Fisiol. Veget., Madrid, vol. 13, p. 122 (andreattita); Potassium-Symposium, Berne, 1955, p. 130 (andreattite). The clay minerals illidromica, illite-hydromica of C. Andreatta (19th List) are divided into: hydromica-Al, hydromica-Mg, a layered series between illite and hydromuscovite (or hydrobiotite); and andreattite-Al, andreattite-Mg, a non-interstratified

series between illite (or mica) and smectite. Named after Prof. Ciro Andreatta (1906–) of Bologna.

Anhydrosaponite. A. Weiss, G. Koch, and U. Hofmann, 1955. Ber. Deutsch. Keram. Gesell., vol. 32, pp. 16–17 (Anhydrosaponit). Artificially dehydrated saponite (from Grosschlattengrün, Bavaria). An endothermal peak at 600° C. is attributed to loss of water from the OH group, with further change at 800° to enstatite $+Al_2O_3$. This is criticized by R. C. Mackenzie, Min. Mag., 1957, vol. 31, pp. 676–678.

Arsenate-belovite. L. K. Yakontova and G. A. Siderenko, 1956. Mém. Soc Russ. Min., vol. 85, p. 297 (арсенат-беловит). The two minerals, belovite (E. I. Nefedov, 1953) and belovite (L. S. Borodin and M. E. Kazakova, 1954) (20th List), are distinguished as arsenate-belovite and phosphate-belovite (фосфат-беловит) respectively. [M.A. **13**–523.]

Arsenopalladinite. F. A. Bannister, G. F. Claringbull, and M. H. Hey, 1955. M. H. Hey, Index of Minerals (Brit. Mus.), 1955, pp. 23, 339. G. F. Claringbull and M. H. Hey, Min. Soc. Notice, 1956, no. 94; M.A. **13**–237. Palladium arsenide, Pd_3As, hexagonal. With gold from Itabira, Brazil. Named from the composition.

Barium-adularia. T. Yoshimura, H. Shirozu, and M. Kimura, 1954. Mem. Fac. Sci. Kyushu Univ., ser. D, vol. 4, p. 163. Adularia from Japan containing BaO 3·36 %. Compare barium-orthoclase (4th List) and barium-sanidine (16th List).

Berillite. M. Fleischer, Amer. Min., vol. 40, p. 787. Direct transliteration of бериллит. (In Russian beryl is берилл.) Synonym of beryllite (20th List). A. H. Chester (Dict. 1896, p. 30) gives berylite as a synonym of beryl.

Beta-roselite. C. Frondel, 1955. Amer. Min., vol. 40, p. 828. $Ca_2Co(AsO_4)_2.2H_2O$, triclinic, previously labelled as 'roselite' from Schneeberg, Saxony. Dimorphous with monoclinic roselite. [M.A. **13**–8.]

Beta-uranophane. C. Frondel, 1956. Amer. Min., vol. 41, p. 551 (beta-uranophane). The monoclinic polymorph of orthorhombic uranophane, $Ca(UO_2)_2(SiO_3)_2(OH)_2.5H_2O$. [M.A. **13**–204.] Synonym of β-uranotile [M.A. **6**–149, **7**–409].

Betekhtinite. A. Schüller and E. Wohlmann, 1955. Geologie Zeitschr. East Berlin, vol. 4, p. 535 (Betechtinit). E. Hörne, Fortschr. Min., 1957, vol. 35, p. 50. $Cu_{10}PbS_6$, orthorhombic needles in ores from Mansfeld, Germany. Named after academician A. G. Betekhtin (А. Г. Бетехтин), mineralogist and geochemist, of Moscow. [M.A. **13**-85.]

Bikitaite. C. S. Hurlbut, 1957. Amer. Min., vol. 42, p. 792. Hydrous silicate, $LiAlSi_2O_6.H_2O$, monoclinic, as white granular aggregates with eucryptite in lithia-pegmatite from Bikita, Southern Rhodesia. Named from the locality.

Birnessite. L. H. P. Jones and A. A. Milne, 1956. Min. Mag., vol. 31, p. 283. A manganese oxide, near $(Na_{0\cdot7},Ca_{0\cdot3})Mn_7O_{14}.2{\cdot}8H_2O$, optically uniaxial negative, with X-ray pattern similar to δ-MnO_2 and manganous manganite [M.A. **9**–227, **10**–105]. From manganese pan in gravel at Birness, Aberdeenshire. Named from the locality. [M.A. **13**–237.]

Bismuth-jamesonite. M. S. Sakharova, 1955, Trudy Min. Mus. Acad. Sci. USSR, no. 7, p. 122 (бисмутовый джемсонит). Sulphosalt, $PbS.(Bi,Sb)_2S_3$, as lead-grey acicular crystals, with ustarasite (q.v.) from Siberia. Variety of jamesonite containing some bismuth and very little iron. [M.A. **13**–164.]

Bismutoniobite. G. Frenzel, 1955. Neues Jahrb. Min., Monatshefte, p. 243 (Bismutoniobit). End-member of the series $Bi(Ta,Nb)O_4$. Compare bismutotantalite, 12th List.

Bobkovite. Y. V. Kazitzyn, 1955. [Kristallografiya, Acad. Sci. USSR, no. 4, p. 116.] Abstracts in Mém. Soc. Russ. Min., 1956, vol. 85, p. 376 (бобковит); Amer. Min., 1957, vol. 42, p. 440. A variety of opal, SiO_2 89·20, H_2O 3·24 %, with small amounts of Al, Fe, Ca, Mg, K. Named after N. A. Bobkov, crystallographer, of Leningrad. [M.A. **13**–521.]

Boltwoodite. C. Frondel and J. Ito, 1956. Science (Amer. Assoc. Adv. Sci.), vol. 124, p. 931. Hydrous potassium uranyl silicate, $K_2(UO_2)_2(SiO_3)_2(OH)_2.5H_2O$, analogous to sklodowskite with K in place of Mg, orthorhombic or monoclinic, as yellow fibres from Utah. Named after Bertram Borden Boltwood (1870–1927), professor of radiochemistry at Yale University; discoverer of ionium. [M.A. **13**–380.]

Bonattite. C. L. Garavelli, 1957. Rend. Soc. Min. Ital., vol. 13, p. 269. $CuSO_4.3H_2O$, monoclinic. Partly dehydrated chalcanthite ($CuSO_4.5H_2O$) from Elba. Named after Prof. Stephano Bonatti of Pisa.

Bonchevite. I. Kostov, 1958. Min. Soc. Notice, 1958, no. 101; Min. Mag., vol. 31, p. 821. Sulphosalt, $PbBi_4S_7$, orthorhombic. From Rhodope Mts., Bulgaria, in quartz-scheelite veins. Named after George Bonchev, Георгий Бончев (1866–1955), formerly professor of mineralogy and petrology, University of Sofia.

Borgniezite. P. de Béthune, 1956. Ann. (Bull.) Soc. Géol. Belgique, vol. 80, p. B 63 (borgniézite); Compt. Rend. Acad. Sci. Paris, 1956, vol. 243, p. 1133 (borgniezite). A soda-amphibole with special optical characters (pleochroism, high extinction), occurring with aegirine in

carbonatite and surrounding schists at Lueshe, Kivu, Belgian Congo. Previously described, but without name, by the author in Mém. Inst. Géol. Univ. Louvain, 1952, vol. 16, p. 278. Named after Georges Borgniez of Auderghem, Belgium.

Bornhardtite. P. Ramdohr and M. Schmitt, 1955. Neues Jahrb. Min., Monatshefte, no. 6, p. 141 (Bornhardtit). Cobalt selenide, Co_3Se_4, cubic (linnaeite group) from Trogtal, Harz. Named after Dr. W. Bornhardt, mine manager. [M.A. **13**–5.]

Boron-edenite. J. A. Kohn and J. E. Comeforo, 1955. Amer. Min. vol. 40, p. 410 (fluor-boron edenite), p. 411, (boron edenite), p. 413 (boron-edenite). Artificial $NaCa_2Mg_5(Si_{3\cdot5}B_{0\cdot5}O_{11})_2F_2$, containing B_2O_3 3·91 %. [MA. **13**–486.]

Boron-phlogopite. R. A. Hatch, R. A. Humphrey, and E. C. Worden, 1956. U.S. Bureau of Mines, report 5283, p. 28 (boron-phlogopite). Artificial $KMg_3BSi_3O_{10}F_2$. [M.A. **13**–448.]

Bursaite. R. Tolun, 1955. Bull. Min. Res. Inst. Turkey, no. 46–47, p. 124. Sulphosalt, $Pb_5Bi_4S_{11}$, as small grey prisms, monoclinic (?). Named after the locality, Bursa (Brusa), NW. Turkey. Evidently a synonym of cosalite ($Pb_2Bi_2S_5$). [M.A. **13**–380.]

Calciborite. E. S. Petrova, 1955. [Min. Syre (Min. Resources), no. 2, p. 218.] Abstracts in Mém. Soc. Russ. Min., 1956, vol. 85, p. 76 (кальциборит, calciborite); Amer. Min., 1956, vol. 41, p. 815. Calcium borate, $Ca_5B_8O_{17}$, monoclinic? White radial aggregates in drill-cores from limestone skarn, Urals. Named from the composition. [M.A. **13**–208.] *See* Frolovite.

Cardosonite. I. Asensio Amor, 1955. Estudios Geológicos, Madrid, no. 25, p. 37 (cardosonita). A mineral (Fe_2O_3 54·07, FeO nil, H_2O 9·21 %) of the dufrenite series, from Coruña, Spain, with X-ray pattern distinct from frondelite and rockbridgeite. Named after Gabriel Martín Cardoso (–1954), professor of crystallography in the University of Madrid. [Amer. Min. **41**–165; M.A. **13**–487.]

Carobbiite. H. Strunz, 1956. Rend. Soc. Min. Ital., vol. 12, p. 212 (Carobbiit). Potassium fluoride, KF, with some NaCl, &c., NaCl structure. Named after Prof. Greido Carobbi of Firenze (Florence) who had earlier [M.A. **6**–444) described the material in fumarole deposits from Vesuvius. [M.A. **13**–382.]

Carpathite. G. L. Piotrovsky, 1955. Min. Sbornik Lvov Geol. Soc., no. 9, p. 120 (карпатит). Hydrocarbon $C_{33}H_{17}O$, yellow monoclinic crystals in contact-zone between diorite-porphyrite and slate from Trans-Carpathians. Named from the locality. Distinct from curtisite

[M.A. **12**–173, 418] from the same locality. (*See* Curtisitoids.) [M.A. **13**–208.]

Cerianite. A. R. Graham, 1955. Amer. Min., vol. 40, p. 560; Contr. Canadian Min., vol. 5, pt. 7. Minute greenish-yellow octahedra in carbonate rock from Lachner, Sudbury, Ontario. Cubic CeO_2 with some ThO_2. Named from its relation to thorianite and uraninite. [M.A. **13**–6.]

Chalconatronite. C. Frondel and R. J. Gettens, 1955. Science (Amer. Assoc. Adv. Sci.), vol. 122, p. 75. R. J. Gettens and C. Frondel, Studies in Conservation (London), 1955, vol. 2, no. 2, p. 64. $Na_2Cu(CO_3)_2.3H_2O$, probably monoclinic, as a greenish-blue incrustation on ancient bronze objects from Egypt. Named from $\chi\alpha\lambda\kappa\sigma\varsigma$, copper, and natron, soda. [M.A. **13**–6, 379.]

Chasovrite. S. V. Potapenko, 1952. [Bull. Acad. Architecture, Ukraine, p. 43.] Criticized by I. D. Sedletzky, Mém. Soc. Russ. Min., 1954, ser. 2, vol. 83, p. 292 (часоврит). A variety of clay mineral (glinite, q.v.) from the Chasovyar deposit in Ukraine. Named from the locality. [M.A. **13**–5.]

Childro-eosphorite. H. Strunz and M. Fischer, 1957. Neues Jahrb. Min., Monatshefte, p. 78 (Childro-Eosphorit), p. 79 (Childrenit-Eosphorit). Midway between childrenite and eosphorite in the isomorphous series $AlPO_4.(Fe,Mn)(OH)_2.H_2O$. From Hagendorf, Bavaria.

Choubnikovite. Bull. Soc. Franç. Min. Crist., 1955, vol. 78, p. 216. French transliteration of шубниковит, shubnikovite (20th List).

Clino-sklodowskite. Author? H. Strunz, Min. Tab., 3rd edit., 1957, p. 276 (Klino-Sklodowskit). Monoclinic, $Mg(H_3O)_2[UO_2|SiO_4]_2.3H_2O$, as distinct from sklodowskite, orthorhombic (?), $Mg[UO_2|SiO_3OH]_2.5H_2O$.

Combeite. T. G. Sahama and K. Hytönen, 1957. Min. Soc. Notice, no. 98; Min. Mag., 1957, vol. 31, p. 503; M.A. **13**–555. $Na_4Ca_3Si_6O_{16}(OH,F)_2$, rhombohedral. In nephelinite from Kivu, Belgian Congo. Named after Arthur Delmar Combe (1893–1949), Geological Survey of Uganda.

Corencite. C. Mira, 1939. [Rev. Matér. Const., Trav. Publ., no. 359, p. 87.] P. F. Kerr and P. K. Hamilton, Amer. Petrol. Inst., Clay mineral standards, 1949, rep. no. 1, p. 16. Synonym of nontronite.

Cornubite. G. F. Claringbull, M. H. Hey, and A. Russell, 1958. Min. Mag., vol. 31, p. 792 [M.A. **13**–558]. Basic copper arsenate, $Cu_5(AsO_4)_2(OH)_4$, dimorphous and associated with cornwallite. The name was provisionally given as cornubianite (Min. Soc. Notice, 1957, no. 99), earlier applied to a metamorphic rock, hornfels (H. S. Boase, Trans.

Roy. Geol. Soc. Cornwall, 1832, vol. 4, pp. 390, 394). Named from the locality, *Cornubia*, *Cornubian*, medieval Latin, Cornwall, Cornish.

Curtisitoids. I. V. Grinberg and V. M. Shimansky, 1954. Min. Sbornik Lvov Geol. Soc., no. 8, p. 107 (кертиситоиди). Group name for hydrocarbons allied to curtisite (11th List) and carpathite (q.v.) differing in colour, composition, and melting-point. [M.A. **13**–120.]

Devillite. Dana, Syst. Min. 7th edit, 1951, p. 590. Synonym of devilline (F. Pisani, 1864). Liable to be confused with similar names with ending *-ite*.

Doloresite. T. W. Stern, L. R. Stieff, H. T. Evans, and A. M. Sherwood, 1957. Amer. Min., vol. 42, p. 587. H. T. Evans and M. E. Mrose, Acta Cryst., 1958, vol. 11, p. 57. Hydrous vanadium oxide, $3V_2O_4.4H_2O$, monoclinic (pseudo-orthorhombic). Dark-brown alteration product of montroseite in sandstone from several mines on the Colorado Plateau. Named from the Dolores river, Colorado.

Doverite. W. L. Smith, J. Stone, D. D. Riska, and H. Levine, 1955. Science (Amer. Assoc. Adv. Sci.), vol. 122, p. 31. Fluo-carbonate of yttrium and calcium, $YtFCO_3.CaCO_3$, as fine-grained aggregates giving an X-ray pattern similar to that of synchysite. From an iron mine at Dover, Morris Co., New Jersey. Named from the locality. [M.A. **13**–7.]

Duttonite. M. E. Thompson, C. H. Roach, and R. Meyrowitz, 1956. Science (Amer. Assoc. Adv. Sci.), vol. 123, p. 990; Amer. Min., 1957, vol. 42, p. 455. H. T. Evans and M. E. Mrose, Bull. Geol. Soc. Amer., 1956, vol. 67, p. 1693 (abstract); Acta Cryst., 1958, vol. 11, p. 58. Vanadium hydroxide, $VO(OH)_2$ or $V_2O_4.2H_2O$, monoclinic (pseudo-orthorhombic), as minute pale-brown scales; an alteration product of montroseite in sandstone from Colorado. Named after Clarence Edward Dutton (1841–1912), an early worker on the Geological Survey in Colorado. [M.A. **13**–378, 379, 524.]

Eisenalabandin. P. Ramdohr, 1957. Neues Jahrb. Min., vol. 91, p. 89 (Eisenalabandin), p. 90 (Fe-alabandin). Alabandine containing much FeS in solid solution, (Mn,Fe)S. As minute grains with native iron and troilite in basalt from Bühl, Kassel. Abstract in Amer. Min. **43**–378 (Iron-alabandite). Ferroalabandine more suitable for international use.

Ericaite. Author? H. Strunz, Min. Tab., 2nd edit., 1949, p. 135; 3rd edit., 1957, p. 185 (Ericait, Manganboracit, α-Ericait). Abstracts in Amer. Min., 1956, vol. 41, p. 372. Few analyses of boracite show the presence of MnO (up to 2·32 %); iron-boracite = huyssenite contains FeO (up to 35·26 %). Etymology?

Eunicite. J. E. Paiva Hetto, 1955. [Engenharia, mineria e metalurgia, vol. 22, no. 128, p. 99 (eunicita).] Abstracts in Mém. Soc. Russ. Min., 1956, vol. 85, p. 382 (эвнисит) and Amer. Min., 1957, vol. 42, p. 441. A variety of montmorillonite from the decomposition of melaphyre at Serra de Botucatu, Portugal. Etymology?

Ezcurrite. S. Muessig and R. D. Allen, 1957. Econ. Geol., vol. 52, p. 426. Hydrous sodium borate, $2Na_2O.5B_2O_3.7H_2O$, with characters very similar to those of kernite ($Na_2B_4O_7.4H_2O$). Associated with kernite, borax, tincalconite in the Tincalayu mine, prov. Salta, Argentina. Named after Juan Manuel de Ezcurra, manager of the mine. *See* Metakernite (14th List). [M.A. **13**–623.]

Feldspathides. A. Michel-Lévy, Structures et classification des roches éruptives, Paris, 1889, p. 38. A collective term to include leucite, nepheline, melilite, sodalite, haüyne, nosean, present in alkalic rocks. Later altered to felspathoids. Compare Lenad (5th List), Feloid (10th List), Foid (q.v.).

Ferri-hydroxykeramohalite. A. Dubanský, 1956. Chem. Listy, Praha, vol. 50, p. 1350 (ferri-hydroxykeramohalit). $(Al,Fe)_4(SO_4)_5(OH)_2.21H_2O$, with Al_2O_3 12·54, Fe_2O_3 11·58 %. (*See* Hydroxykeramohalite.)

Ferri-ilmenite. R. Chevallier, J. Bolfa, and S. Mathieu, 1955. Bull. Soc. Franç. Min. Crist., vol. 78, p. 310 (ferri-ilménites). Ilmenite containing up to 33 % Fe_2O_3 in solid solution, as distinct from titanohématites (titanhaematite, 17th List) containing up to 33 % TiO_2, in the isomorphous rhombohedral series Fe_2O_3–$FeTiO_3$.

Ferrikerolite. I. A. Rukavishnikova, 1956. [Kora vyvetrivaniya, Acad. Sci. USSR, no. 2, p. 141.] Abstract in Mém. Soc. Russ. Min., 1957, vol. 86, p. 125 (феррикеролит, ferrikerolite). Compact, green variety of kerolite (cerolite), with karpinskite (q.v.) in serpentine. Urals.

Ferroalabandine. *See* Eisenalabandin.

Ferrodickinsonite. D. J. Fisher, 1954. Amer. Min., vol. 39, p. 676 (ferroan dickinsonite), p. 840 (ferro dickinsonite); ibid., 1955, vol. 40, p. 1107 (ferrodickinsonite); Science (Amer. Assoc. Adv. Sci.), 1955, vol. 121, p. 312. Alternative name for arrojadite (11th List). A dickinsonite richer in iron. [M.A. **12**–561.] *See* Manganodickinsonite.

Ferroferrimargarite. A. I. Ginzburg, 1955. Trudy Min. Mus. Acad. Sci. USSR, no. 7, p. 75 (ферроферримаргарит). A brittle mica, chemical variety of margarite. [M.A. **13**–209, 521.]

Ferrofillowite. D. J. Fisher, 1955. Bull. Geol. Soc. Amer., vol. 66, p. 1558. Na-Fe-Mn phosphate. 'The Fe″ compound ferrodickinsonite [q.v.], heated in vacuum, inverts irreversibly to ferrofillowite.' Synonym of fillowite (Brush and Dana, 1879).

Ferroselite. E. Z. Buryanova and A. I. Komkov, 1955. Doklady Acad. Sci. USSR, vol. 105, p. 812 (ферроселит). Iron selenide $FeSe_2$, orthorhombic, resembling marcasite, from Tuva, Siberia. Named from the composition. Compare achavalite (18th List, M.A. **12**–236), and eskebornite (19th List). [M.A. **13**–84.]

Ferrous riebeckite. W. G. Ernst, 1957. Ann. Rep. Geophysical Lab., for 1956–57, p. 228 (ferrous riebeckite). Artificial $Na_2Fe''_3Fe''_2Fe'''Si_8O_{22}(OH)_2$. *See* Magnesian riebeckite.

Ferutite. Y. V. Kazitzyn, 1954. Mém. Soc. Russ. Min., vol. 83, p. 425 (ферутит). The mineral from Mozambique [Min. Mag. **29**–101, 292], previously referred to davidite, is hexagonal with a distinctive X-ray pattern. Named from the composition, Fe, U, Ti. Abstracts in Bull. Soc. Franç. Min. Crist., 1956, vol. 79, p. 181 (ferrutite); Amer. Min., 1958, vol. 43, p. 382. *See* Mavudzite.

Fluor-edenite. J. A. Kohn and J. E. Comeforo, 1955. Amer. Min., vol. 40, p. 410 (fluor-edenite). Artificial $NaCa_2Mg_5(Si_{3\cdot5}Al_{0\cdot5}O_{11})_2F_2$. Compare fluor-richterite (19th List). [M.A. **13**–486.]

Foid, foidal. A. Johannsen, 1917. Journ. Geol., Chicago, vol. 25, pp. 69–71; Descriptive petrology of igneous rocks, 1931, vol. 1, pp. 141, 174. Abbreviations of felspathoids, felspathoidal. Compare feldspathides (q.v.), feloids (10th List), quarfeloids (10th List).

Francevillite. G. Branche, M. E. Ropert, F. Chantret, B. Morignat, and R. Pouget, 1957. Compt. Rend. Acad. Sci. Paris, vol. 245, p. 89; Bull. Techn. Atomic Energy, 1957, vol. 7, p. 14. Hydrous vanadate, $(Ba,Pb)(UO_2)_2(VO_4)_2.5H_2O$, orthorhombic, as yellow impregnations in sandstone from Franceville, French Equatorial Africa. Named from the locality. [M.A. **13**–522.]

Freboldite. H. Strunz, Min. Tab., 3rd edit., 1957, p. 98 (Freboldit). Cobalt selenide, CoSe, hexagonal, pyrrhotine group, artificial. 'Mineral 4' of P. Ramdohr, 1955 [M.A. **13**–6]. Etymology?

Frolovite. E. S. Petrova, 1957. Mém. Soc. Russ. Min., vol. 86, p. 622 (фроловит). Hydrous calcium borate, $CaB_2O_4.3\frac{1}{2}H_2O$. With calciborite (q.v.) in limestone skarn from Novo-Frolov copper mine, Turinsk district, northern Urals.

Galeite. A. Pabst, D. L. Sawyer, and G. Switzer, 1955. Bull. Geol. Soc. Amer., vol. 66, p. 1658 (abstract). $Na_2SO_4.Na(F,Cl)$, trigonal, the

same as schairerite (12th List), but with a difference in the X-ray pattern, the two perhaps intergrown as a polycrystal. From Searles Lake, California. Named after Mr. W. A. Gale. [M.A. **13**–86.]

Gallium-phlogopite. C. Klingsberg and R. Roy, 1957. Amer. Min., vol. 42, p. 629 (gallium phlogopite), p. 321 (Ga-phlogopite). Artificially prepared $KMg_3GaSi_3O_{10}.(OH)_2$, with Ga in place of Al in phlogopite.

Garrelsite. C. Milton, J. M. Axelrod, and F. S. Grimaldi, 1955. Bull. Geol. Soc. Amer., vol. 66, p. 1597 (abstract). Boro-silicate, $(Ba,Ca,Mg)_4B_4(BO_4)_2(SiO_4)_2(OH)_2.2H_2O$. Small monoclinic crystals related to datolite, from an oil boring at Onray, Utah. Named after Robert M. Garrels, of Harvard University. [M.A. **13**–86.]

Gearksite. I. F. Grigoriev and E. I. Dolomanova, 1951. Trudy Min. Mus. Acad. Sci. USSR, no. 3, p. 93 (геарксит). M. D. Dorfman, ibid., p. 97. Ca-Al hydrofluoride, $CaAl_3(F,OH)_{11}.H_2O$, as white powdery aggregates in hydrothermally metamorphosed sediments, from Transbaikal. Named from analogy with gearksutite ($CaAlF_4OH.H_2O$) and paragearksutite (18th List).

Germanium-phenakite. A. Van Valkenburg and C. E. Weir, 1957. Bull. Geol. Soc. Amer., vol. 68, p. 1809 (germanium phenacite). Artificial $2BeO.GeO_2$, with Ge in place of Si.

Gerstleyite. C. Frondel and V. Morgan, 1956. Amer. Min., vol. 41, p. 839. Sodium sulphantimonite and sulpharsenite, $Na_4As_2Sb_8S_{17}.6H_2O$, as red spherules, monoclinic (?) with borates in clay from Kramer, California. Named after Mr. J. M. Gerstley, of a borax company. [M.A. **13**–303.]

Ginzburgite. F. V. Chukhrov, 1955. [Colloids in the earth's crust, Acad. Sci. USSR, p. 598.] Abstracts in Mém. Soc. Russ. Min., 1956, vol. 85, p. 382 (гинзбургиты, ginsburgites) and Amer. Min., 1957, vol. 42, p. 440. A general term for clay minerals with composition $(Al,Fe)_2O_3:SiO_2$ ranging from 1:1 to 1:1·25. Named after I. I. Ginzburg. [M.A. **13**–628.]

Glinite. S. V. Potapenko, 1952. [Publ. Acad. Architecture, Ukraine, p. 43]. Criticized by I. D. Sedletzky, Mém. Soc. Russ. Min., 1954, ser. 2, vol. 83, p. 289 (глинит). A group name for clay minerals, from глина, clay. Compare Clayite (5th List). *See* Chasovrite. [M.A. **13**–5.]

Gonyerite. C. Frondel, 1955. Amer. Min., vol. 40, p. 1090. A chlorite rich in manganese (MnO 33·83 %) and poor in aluminium (Al_2O_3 0·58 %), from Långban, Sweden. Named after Forest A. Gonyer, analytical chemist, of Harvard University. [M.A. **13**–87.]

Götzenite. T. G. Sahama and K. Hytönen, 1957. Min. Soc. Notice, no. 98; Min. Mag., 1957, vol. 31, p. 503; M.A. **13**–555. $(Ca,Na,Al)_7(Si,Ti)_5O_{15}F_{3\cdot5}$, triclinic, rinkite group. In nephelinite from Kivu, Belgian Congo. Named after Count G. A. von Götzen, German traveller in East Africa.

Grayite. S. H. U. Bowie, 1957. Summ. Progr. Geol. Surv. Great Britain for 1956, p. 47. Thorium phosphate, hexagonal, related to rhabdophane. Pale yellow, powdery, in lithia-pegmatite from Southern Rhodesia. [M.A. **13**–494.]

Gyulekhite. C. M. Khalife-Zade, 1957. [Doklady Acad. Sci. Azerbaijan SSR, 1957, vol. 13, p. 647.] Abstract in Mém. Soc. Russ. Min., 1958, vol. 87, p. 83 (гюлехит, gewlekhite, Gülechit). Hydrous silicate, SiO_2 31·44, Al_2O_3 14·50, Fe_2O_3 29·88, FeO 3·52, MgO 4·00, K_2O 3·71, H_2O+ 8·09, H_2O- 3·31 %. Named from the locality, Гюлех village, SE. Caucasus.

Häggite. H. T. Evans and M. E. Mrose, 1958. Acta Cryst., vol. 11, p. 57. Vanadium hydroxide, $V_2O_3.V_2O_4.3H_2O = V_2O_2(OH)_3$, as black monoclinic crystals in sandstone from Wyoming. Named after Prof. Gunnar Hägg of Uppsala University.

Hastite. P. Ramdohr and M. Schmitt, 1955. Neues Jahrb. Min., Monatshefte, no. 6, p. 140 (Hastit). Cobalt selenide, $CoSe_2$, orthorhombic (marcasite group). From Trogtal, Harz. Named after Dr. P. F. Hast, mining director. [M.A. **13**–5.]

Hawleyite. R. J. Traill and R. W. Boyle, 1955. Amer. Min., vol. 40, p. 555; Contr. Canadian Min., vol. 5, pt. 7. Cubic CdS, dimorphous with greenockite, as a yellow powder on blende. Named after Prof. James E. Hawley, of Queen's University, Kingston, Ontario. Compare optically isotropic xanthochroite (8th List). [M.A. **13**–7.]

Heidornite. W. v. Engelhardt and H Füchtbauer, 1956. Heidelberg. Beitr. Min. Petr., vol. 5, p. 177 (Heidornit). Borate, sulphate, and chloride, $Na_2Ca_3Cl(SO_4)_2B_5O_8(OH)_2$, monoclinic, as transparent spear-like crystals (up to 7 cm.) with glauberite from a deep boring in anhydrite at Nordhorn, Hannover. Named after Dr. Fritz Heidorn, geologist, of Bentheim. [M.A. **13**–382.]

Hibonite. H. Curien, C. Guillemin, J. Orcel, and M. Sternberg, 1956. Compt. Rend. Acad. Sci. Paris, vol. 242, p. 2845. L. Delbos, ibid., 1957, vol. 244, p. 214. Mixed oxides of aluminium, &c., $(Al,Fe''',Ti,Si,Mg,Fe'')_{12}(Ca,\text{rare-earths})O_{19}$, dark-brown, hexagonal crystals in metamorphic limestone with plagioclase, corundum, spinel, and thorianite, from southern Madagascar. Named after P. Hibon, who found the material. [M.A. **13**–380.]

Honessite. A. V. Heyl, C. Milton, and J. M. Axelrod, 1956. Bull. Geol. Soc. Amer., vol. 67, p. 1706 (abstract). Hydrous basic nickel-iron sulphate, as a green or brown powdery weathering product of millerite, from Wisconsin. Named after Prof. Arthur Pharaoh Honess (1887–1942).

Hydrocassiterite. H. Strunz, Min. Tab., 3rd edit., 1957, p. 151 (Hydro-Cassiterit). Synonym of souxite = varlamoffite (18th List).

Hydrogen-autunite. C. Frondel, 1950. Amer. Min., vol. 35, p. 762 (hydrogen-autunite). V. Ross, ibid., 1955, vol. 40, p. 917. Artificial base-exchange product, $HUO_2PO_4.4H_2O$, tetragonal. [M.A. **13**–7.]

Hydronasturan. R. V. Getzeva, 1956. [Atomic Energy, Moscow, no. 3, p. 135.] Abstracts in Mém. Soc. Russ. Min., 1957, vol. 86, p. 117 (гидронастуран, hydronasturan); Amer. Min., 1957, vol. 42, p. 442. $UO_2.kUO_3.nH_2O$. Compact, amorphous, black, in oxidized ore. Named from the composition. (настуран = pitchblende.) *See* urhite. [M.A. **13**–385.]

Hydroxykeramohalite. A. Dubanský, 1956. Chem. Listy, Praha, vol. 50, p. 1350 (hydroxykeramohalit). $Al_4(SO_4)_5(OH)_2.21H_2O$. Derivative of keramohalite (or alunogen), from Dubnik, Slovakia.

Iriginite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 9 (priguinite). Later publications, abstracts: Amer. Min., 1956, vol. 41, p. 816 (priguinite), 1958, vol. 43, p. 379 (iriginite); Mém. Soc. Russ. Min., 1953, vol. 87, p. 80 (иригинит, iriginite). $UO_3.2MoO_3.4H_2O$. Etymology?

Iron-alabandite. *See* Eisenalabandin.

Isostannite. G. F. Claringbull and M. H. Hey, 1955. Min. Soc. Notice, 1955, no. 91 [M.A. **13**–31]; M. H. Hey, Index of Minerals (Brit. Mus.) 1955, pp. 34, 468, 609. Cubic (isometric) modification of Cu_2FeSnS_4, as distinct from tetragonal stannite.

Istisuite. M. A. Kashkay and A. I. Mamedov, 1955. [Doklady Acad. Sci. Azerbaijan, vol. 11, no. 1, p. 21]; abstract in Mém. Soc. Russ. Min., 1955, ser. 2, vol. 84, p. 347 (истисуит). $(Ca,Na)_7(Si,Al)_8(O,OH)_{24}$, monoclinic. With wollastonite in skarn from Istisu (Истису), a health resort on the Terter river, Azerbaijan republic. [M.A. **13**–207.]

Jagoite. R. Blix, O. Gabrielson, and F. E. Wickman, 1957. Arkiv. Min. Geol., Stockholm, vol. 2, no. 18, p. 215 (jagoite). $(Pb,Ca)_3Fe'''Si_3O_{10}(Cl,OH)$; analysis, SiO_2 22·35, Pb 64·26 %, and fractional percentages of Al, Be, K, Mg, Mn, Na, Ti. Trigonal, yellow-green micaceous plates with melanotekite in iron ore. This is the tenth lead silicate from Långban, Sweden. Named after John B. Jago, mineral collector of San Francisco.

Janovite. Still another variation of janite (13th List), janowaite (15th List), and yanite (15th List). [M.A. **13**–180.]

Kadmoselite. E. Z. Buryanova, G. A. Kovalev, and A. I. Komkov, 1957. Mém. Soc. Russ. Min., vol. 86, p. 626 (кадмоселит). Cadmium selenide, CdSe, hexagonal, minute black grains. Named from the composition.

Kaliophyllite. Error for kaliophilite. Compare Corundophyllite (20th List). [M.A. **13**–493.]

Kandite. Clay Min. Bull., 1955, vol. 2, pp. 295, 296. Group name to include kaolinite, nacrite, dickite, halloysite. A portmanteau word, but overlooking halloysite.

Karpatite. Russian карпатит for carpathite (q.v.).

Karpinskite. I. A. Rukavishnikova, 1956. [Kora vyvetrivaniya, Acad. Sci. USSR, no. 2, p. 164.] Abstract in Mém. Soc. Russ. Min., 1957, vol. 86, p. 124 (карпинскит). $(Ni,Mg)_2Si_2O_5(OH)_2$, containing NiO 21·12, MgO 17·56 %, compact, greenish-blue, with cerolite minerals (nickel-β-kerolite, ferrikerolite, qq.v.) in crevices in serpentine. Urals. Named after A. P. Karpinsky. Not to be confused with karpinskyite (q.v.).

Karpinskyite. L. L. Shilin, 1956. Doklady Acad. Sci. USSR, vol. 107, p. 737 (Карпинскиит), English table of contents (karpinskyite). Radial aggregates of white hexagonal needles in pegmatite [from Kola peninsula]. $Na_2(Be,Zn,Mg)Al_2Si_6O_{16}(OH)_2$. Named after Alexander Petrovich Karpinsky, Александр Петрович Карпинский (1847–1936), Russian geologist. [Min. Mag. **25**–293, M.A. **13**–209.]

Kašparite. A. Dubanský, 1956. Chem. Listy, Praha, vol. 50, p. 1352 (Kašparit). $(Mg,Co)Al_3(SO_4)_5OH.28H_2O$. Variety of pickeringite containing CoO 1·52 %, from Dubnik, Slovakia. Named after Prof. Jan V. Kašpar of Praha. [Amer. Min. **42**–919.]

Kertisite. Russian кертисит for curtisite. *See* Curtisoids.

Këwhile Z. V. Orlova, 1956. [Trudy Magadan Sci. Research Inst. 1956, p. 76.] Abstract in Mém. Soc. Russ. Min., 1958, vol. 87, p. 76 (кёстерит, custerite, Kösterit). (Cu,Sn,Zn)S, containing Cu 30·56, Sn 25·25, Zn 11·16, S 23·40%. In quartz-sulphide ore from Këster, Magadan, Yakutia, NE. Siberia. Named from the locality.

Kettnerite. L. Žak and V. Syneček, 1956. Časopis Min. Geol., vol. 1, p. 195. $CaF(BiO)CO_3$, tetragonal, brown to yellow crystals with bismuth, fluorite, &c., in pegmatite from Krupka, Bohemia. Named after Radim Kettner, professor of geology, Karlova University, Praha.

Kingite. K. Norrish, L. E. R. Rogers, and R. E. Shapter, 1956. Min. Soc. Notice, no. 94; Min. Mag., 1957, vol. 31, p. 351. Hydrous aluminium phosphate, $Al_2O_3.Al(OH)_3.P_2O_5.9H_2O$, as white nodules in phosphate deposits in South Australia. Named after Mr. D. King, geologist, Department of Mines, South Australia. (*See* Meta-kingite.)

Kirschsteinite. T. G. Sahama and K. Hytönen, 1957. Min. Mag., vol. 31, p. 698. $CaFeSiO_4$ (69·4 mol. %, with some Mg and Mn), orthorhombic, monticellite group. With combeite and götzenite (qq.v.) in nephelinite from Kivu, Belgian Congo. Named after the late Dr. Egon Kirschstein, German geologist.

Knipovitchite. Bull. Soc. Franç. Min. Crist., 1955, vol. 78, p. 218. French transliteration of книповичит, knipovichite (20th List).

Kupletskite. E. I. Semenov, 1956. Doklady Acad. Sci. USSR, vol. 108, p. 933 (Куплетскит). A variety of astrophyllite rich in manganese (MnO 27·65 %), in pegmatite from Kola. Named after Boris Mikhailovich Kupletsky, Борис Михаилович Куплетский, Russian mineralogist. Abstract in Bull. Soc. Franç. Min. Crist., 1957, vol. 80, p. 212 (koupletskite). [M.A. **13**–384.]

Kurnakite. E. Y. Rode, 1955. Trans. First Congress of Thermography (Kazan, 1953), Acad. Sci. USSR, 1955, p. 217 (курнакит). Two modifications of Mn_2O_3, usually confused with braunite and bixbyite: α-kurnakite is tetragonal and β-kurnakite is cubic. Named after N. S. Kurnakov. [M.A. **13**–302.] Not to be confused with kurnakovite (16th List).

Kurumsakite. E. A. Ankinovich, 1954. [Izv. Acad. Sci. Kazakhstan, no. 134, Geol. ser. no. 18, p. 116.] Abstract in Mém. Soc. Russ. Min., 1955, vol. 84, p. 343 (курумсакит). $8(Zn,Ni,Cu)O.4Al_2O_3.V_2O_5.5SiO_2.27H_2O$, orthorhombic? In bituminous shale from Kurumsk, Kara-tau Mts., Kazakhstan. Named from the locality. [M.A. **13**–207.]

Labuntzovite. E. I. Semenov and T. A. Burova, 1955. Doklady Acad. Sci. USSR, vol. 101, p. 1113 (лабунцовит). Abstracts in Amer. Min., vol. 41, p. 163 (labuntsovite) and Bull. Soc. Franç. Min. Crist., vol. 79, p. 333 (labountsovite). Hydrous titano-silicate, $(K,Na,Ba,Ca,Mn)(Ti,Nb)Si_2(O,OH)_7.\frac{1}{2}H_2O$, orthorhombic, from Kola, Russia. Originally described by A. N. Labuntzov [M.A. **3**–235] as titaniferous elpidite (titano-elpidite, 11th List), but now shown to contain only a trace of ZrO_2 with TiO_2 25·49, Nb_2O_5 1·45 %. Named after Alexander Nikolaevich Labuntzov, Александр Николаевич Лабунцов, formerly of the Lomonosov Institute, Moscow. [M.A. **13**–4.]

Ledikite. G. Brown and others, 1955. Clay Min. Bull., vol. 2, pp. 299, 300. 'The trioctahedral analogue of illite', as an alteration product of biotite in soil-clay from East Ledikin, Aberdeenshire. Named from the locality. Compare cardenite (20th List).

Lermontovite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 8 (lermontovite). Later publications, abstracts: Amer. Min., 1956, vol. 41, p. 816, 1958, vol. 43, p. 379; Mém. Soc. Russ. Min., 1958, vol. 87, p. 81 (лермонтовит, lermontovite). $(U,Ca,rare\text{-}earths)_3(PO_4)_4.6H_2O$. Named after Mikhil Yurevich Lermontov (1814–44), Russian poet of Scottish origin.

Lesserite. C. Frondel, V. Morgan, and J. L. T. Waugh, 1956. Amer. Min., vol. 41, p. 927. Hydrous magnesium borate, $Mg_2B_6O_{11}.15H_2O$, monoclinic, dimorphous with triclinic inderite, from Kramer, California. Named after Mr. Federico Lesser, of the borate industry. [M.A. **13**–303.]

Lithiophosphate. V. V. Mathias and A. M. Bondareva, 1957. Doklady Acad. Sci. USSR, vol. 112, p. 124 (литиофосфат, lithiophosphate). Lithium phosphate, Li_3PO_4, as white to colourless masses in pegmatite from Kola. It is a hydrothermal alteration product of montebrasite, and weathers to mangan-apatite and davisonite. Named from the composition. The suffix *-ate* is new for mineral names (except agate) and may be confused with chemical and other terms; for example, selenite ($CaSO_4.2H_2O$ and $CaSeO_3$), evaporate, precipitate, separate. [M.A. **13**–383.]

Lizardite. E. J. W. Whittaker and J. Zussman, 1955. Min. Soc. Notice, no. 91; Min. Mag., 1956, vol. 31, pp. 108, 118; J. Zussman and others, Amer. Min., 1957, vol. 42, p. 134. A platy serpentine mineral with X-ray *c*-axis half that of chrysotile. Named from the locality, Lizard, Cornwall.

Lodochnikite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 9 (lodochnikite). Later publications, abstracts: Amer. Min., 1957, vol. 42, p. 307 (lodochnikite, lodochnikovite), Amer. Min. **43**–380; Mém. Soc. Russ. Min., 1958, vol. 87, p. 78 (лодочникит, lodochnikite). $2(U,Th)O_2.3UO_3.14TiO_2$. Named after Vladimir (= Wartan) N. Lodochnikov, Владимир Н. Лодочников (1887–1942). Not to be confused with lodochnikovite of E. I. Nefedov, 1953 (20th List).

Lodotchnikovite, Lodotschnikowit. French (Bull. Soc. Franç. Min. Crist., 1955, vol. 78, p. 219) and German (Geologie Zeitschr., East Berlin, 1955, vol. 4, p. 528) transliterations of лодочниковит, lodochnikovite of E. I. Nefedov, 1953 (20th List).

Mafite. A. Johannsen, 1917. Journ. Geol. Chicago, vol. 25, p. 70. Collective name for dark rock-forming minerals. Metamorphism of ferromagnesian through the stages femag and mafic.

Maghæmite. P. T. Davey and T. R. Scott, 1957. Nature, London, vol. 179, p. 1363. Variant of maghemite (12th List).

Magnesian glaucophane. W. G. Ernst, 1957. Ann. Rep. Geophysical Lab., for 1956–57, p. 228 (magnesian glaucophane). Artificial $Na_2Mg_3Al_2Si_3O_{22}(OH)_2$.

Magnesian riebeckite. W. G. Ernst, 1957. Ann. Rep. Geophysical Lab., for 1956–57, p. 228 (magnesian riebeckite). Artificial $Na_2Mg_3Fe_2'''Si_8O_{22}(OH)_2$. *See* Ferrous riebeckite.

Magnussonite. O. Gabrielson, 1956. Arkiv Min. Geol. Stockholm, vol. 2, p. 133. Arsenite of Mn, &c. $(Mn,Mg,Cu)_5(AsO_3)_3(OH,Cl)$, cubic, as green crusts on dolomite from Långban, Sweden. Named after Nils H. Magnusson, director of the Geological Survey of Sweden. [M.A. **13**–381.]

Manganboracite. *See* Ericaite.

Manganodickinsonite. D. J. Fisher, 1957. Amer. Min., vol. 42, p. 662 (mangano-dickinsonite). Synomyn of dickinsonite (Brush and Dana, 1878). *See* Ferrodickinsonite.

Mauritzite. L. Tokody, T. Mándy, and S. Nemes-Varga, 1957. Neues Jahrb. Min. Monatshefte, p. 33 (Mauritzit). Hydrous oxides, $(Fe''',Al)_2O_3.2(Mg,Fe'')O.5H_2O$, as bluish-black rods in altered andesite from Hungary. The structure is similar to that of montmorillonite with $(OH)_4$ in place of SiO_2, but containing much intermixed quartzine. Named after Prof. Béla Mauritz (1881–) of Budapest. [M.A. **13**–381.]

Mavudzite. A. V. P. Coelho, 1954. [Garcia de Orta, Rev. junta missões geogr. e invest. do Ultramar, vol. 2, p. 209.] Bibliography of geology, Geol. Soc. Amer., 1955, vol. 19, p. 369; Amer. Min., 1956, vol. 41, p. 164. A metamict radioactive mineral from Mavudzi, Tete district, Mozambique. Named from the locality. Previously described [Min. Mag. **29**–101, 292] as a variety of davidite. *See* Ferutite.

Mesomicrocline. Author? H. Strunz, Min. Tab., 3rd edit., 1957, p. 334 (Mesomikroklin). Triclinic pseudo-monoclinic, $K(Al,Si)_2Si_2O_8$. Greek μεσος, middle.

Meta-kingite. K. Norrish, L. E. R. Rogers, and R. E. Shapter, 1957. Min. Mag., vol. 31, p. 351. An artificially, partially dehydrated form, $Al_2O_3.Al(OH)_3.P_2O_5.4H_2O$, of kingite (q.v.).

Metanováčekite. C. Frondel, 1956. Prof. Paper U.S. Geol. Surv., no. 300, p. 578 (metanovacekite). $Mg(UO_2)_2(AsO_4)_2.8H_2O$, partly de-

hydrated form of nováčekite (19th List). H. Strunz, Min. Tab., 3rd edit., 1957, p. 253 (Meta-Novačekit), $Mg(UO_2)_2(AsO_4)_2.4H_2O$, tetragonal.

Micheewit. E. I. Nefedov, Geologie, Zeits. Geol., East Berlin, 1955, vol. 4, p. 526. German spelling of mikheevite (20th List). Named after Viktor Ivanovich Mikheev, Виктор Иванович Михеев (1912–56), X-ray crystallographer. [M.A. **13**–85.]

Microantiperthite. A. F. Buddington, J. Fahey, and A. Vlisidis, 1955. Amer. Journ. Sci., vol. 253, p. 503. A fine intergrowth of potash-felspar and plagioclase with the former predominating. Compare Antiperthite (4th List).

Minguzzite. C. L. Garavelli, 1955. Rend. Accad. Lincei, Cl. Sci. fis. mat. nat., ser. 8, vol. 18, p. 400. Oxalate of potassium and ferric iron, $K_3Fe(C_2O_4)_3.3H_2O$, green monoclinic crystals, with oxalite = humboldtine, $FeC_2O_4.2H_2O$, in limonite from Elba. Named in memory of Carlo Minguzzi (1910–1953), Italian mineralogist. [M.A. **13**–86.]

Mogensenite. A. F. Buddington, J. Fahey, and A. Vlisidis, 1955. Amer. Journ. Sci., vol. 253, p. 409. A titaniferous magnetite containing exsolution ulvöspinel. Named after Fredrik Mogensen, of Djursholm, Sweden, who described ulvöspinel (Fe_2TiO_4, 18th List). *See* Titanmagnetite.

Moluranit. Author? Guide to USSR exhibit on Atomic Energy, Geneva, 1955, p. 9 (moluranite). Later publications, abstracts: Amer. Min., 1956, vol. 41,p. 816, Amer. Min. **43**–381, $UO_2.2UO_3.5MoO_3.12H_2O$; Mém. Soc. Russ. Min., 1958, vol. 87, p. 79 (молуранит), $UO_2.2UO_3.5MoO_3.12H_2O$? Named from the composition.

Mountainite. J. A. Gard and H. F. W. Taylor, 1957. Min. Soc. Notice, 1957, no. 97; Min. Mag., 1957, vol. 31, p. 611. A fibrous zeolitic mineral containing no Al_2O_3, unit-cell contents $(Ca,Na_2,K_2)_{16}Si_{32}O_{80}.24H_2O$, monoclinic. Closely associated and confused with rhodesite (q.v.) from Bultfontein mine, Kimberley, South Africa. Named after Prof. Edgar Donald Mountain (1901–) of Rhodes University, Grahamstown.

Nekoite. J. A. Gard and H. F. W. Taylor, 1955. Min. Soc. Notice, no. 90; Min. Mag., 1956, vol. 31, p. 5. A dimorphous triclinic form of $CaO.2SiO_2.2H_2O$, applied to the 'okenite' from Crestmore, California, which differs in optical and X-ray data from okenite from other localities. Anagrammatic name.

Nenadkevite. V. A. Polikarpova, 1956. [Atomic Energy, Moscow, no. 3, p. 132.] Abstract in Mém. Soc. Russ. Min., 1957, vol. 86, p. 123

(ненадкевит). Earlier note in guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 7 (nenadkevite). Abstracts in Amer. Min. **41**–816, **42**–441. Composition variously given as $(U^{iv},Yt,Ce,Th)U^{vi}(Ca,Mg,Pb)(SiO_4)_2(OH)_4.nH_2O$ and $U^{vi}(U^{iv},Th)(Mg,Ca,Pb)_3(SiO_4)_2(OH)_8.nH_2O$. Named after Konstantin Avtonomovich Nenadkevich, Константин Автономович Ненадкевич, Russian mineralogist and geochemist. Not to be confused with Nenadkevichite of M. V. Kuzmenko and M. E. Kazakova, 1955 (20th List). [M.A. **13**–385.]

Neomesselite. C. Frondel, 1955. Amer. Min., vol. 40, p. 828. $(Ca,Fe,Mn,Mg)_3(PO_4)_2.2H_2O$, triclinic, from Palermo mine, North Groton, New Hampshire. Synonym of messelite (W. Muthmann, 1889) from Messel, Hesse. [M.A. **13**–8.]

Nickel-β-kerolite. I. A. Rukavishnikova, 1956. [Kora vyvetrivaniya, Acad. Sci. USSR, no. 2, p. 141.] Abstract in Mém. Soc. Russ. Min., 1957, vol. 86, p. 125 (никелевый β-керолит, nickel-β-kerolite). $(Mg,Ni)_3Si_4O_{10}(OH)_2.H_2O$, containing MgO 20·05, NiO 18·06 %, compact, bright green, with karpinskite (q.v.) in serpentine. Urals.

Nickel-phlogopite. C. Klingsberg and R. Roy, 1957. Amer. Min., 1957, vol. 42, p. 629 (nickel phlogopite), p. 631 (Ni-phlogopite). Artificially prepared $KNi_3AlSi_3O_{10}(OH)_2$, with Ni in place of Mg (Mg-phlogopite).

Nickel-vermiculite. C. S. Ross and E. V. Shannon, Amer. Min., 1926, vol. 11, p. 90 (nickeliferous vermiculite), NiO 11.25%, North Carolina [M.A. **3**–352]. A. P. Nikitina, 1956. [Kora vyvetrivaniya, Acad. Sci. USSR, no. 2, p. 188 (никелевый вермикулит).] Variety of vermiculite containing NiO 8·6 %, from weathering of ultra-basic rocks, Ukraine. [M.A. **13**–514.]

Niboloparite. I. P. Tikhonenkov and M. E. Kazakova, 1957. Mém. Soc. Russ. Min., vol. 86, p. 641 (ниоболопарит). Variety of loparite (10th List) with niobium predominating over tantalum, $(Na,Ce,Ca)(Ti,Nb)O_3$, as black octahedra in alkali-pegmatite from Kola.

Niocalite. E. H. Nickel, 1956. Amer. Min., vol. 41, p. 785, p. 969 (nicolatie). K. Kern, A. Rimsky, and J. C. Monier, Compt. Rend. Acad. Sci. Paris, 1957, vol. 245, p. 2063. Niobo-silicate of calcium, $Ca_4NbSi_2O_{10}(OH,F)$, orthorhombic, as pale yellow prismatic crystals in metamorphic limestone from Oka, Quebec. Named from the composition. [M.A. **13**–211.]

Nolanite. S. C. Robinson, 1955. Bull. Geol. Surv. Canada, no. 31, p. 67. W. H. Barnes and M. M. Qurashi, Amer. Min., 1952, vol. 37, p. 420 (iron vanadate [M.A. **12**–210]). S. C. Robinson, H. T. Evans, W. T. Schaller, and J. J. Fahey, Amer. Min., 1957, vol. 42, p. 619. Iron

vanadate, $3FeO.V_2O_3.3V_2O_4$ or $4FeO.V_2O_3.4V_2O_4$, as minute, black hexagonal plates with uranium ore from Beaverlodge (= Goldfields), Saskatchewan. Intergrown with a second phase ($FeO.2V_2O_4$). Named after Thomas Bennan Nolan (1901–), Director, U.S. Geological Survey.

Obruchevite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 9 (obruchevite), contains U, Ti, Nb, Ta. Later publications, abstracts: Amer. Min., 1957, vol. 42, p. 307, 1958, vol. 43, p. 380, $(Yt,U,Na_2)Ta_2O_6(OH,F)$; Mém. Soc. Russ. Min., 1958, vol. 87, p. 79 (обручевит, obruchevite), $3Na_2O.4(Ca,Fe)O.3Yt_2O_3.(U,Th)O_2$. A. Kalina, Doklady Acad. Sci. USSR, 1957, vol. 117, p. 117, обручевит, variety of pyrochlore in pegmatite from Karelia. Named after the veteran geologist Vladimir Afanasevich Obruchev, Владимир Афанасьевич Обручев (1863–1956).

Orlite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 7 (orlite). Later publications, abstracts: Amer. Min., 1956, vol. 41, p. 816, 1957, vol. 42, p. 307, 1958, vol. 43, p. 381; Mém. Soc. Russ. Min., 1958, vol. 87, p. 83 (орлит, orlite). Formula variously given as $3PbO.3UO_3.4SiO_2.6H_2O$ and '$Pb_3(UO_2)_3Si_2O_7.6H_2O$'. Etymology?

Painite. G. F. Claringbull, M. H. Hey, and C. J. Payne, 1956. Min. Soc. Notice, 1956, no. 95; Min. Mag., 1957, vol. 31, p. 420. Mixed oxide, near $Al_{20}Ca_4BSiO_{37\cdot5}$. A single, small, transparent, dark-red, hexagonal crystal from gem-gravel at Mogok, Burma. Named after Arthur Charles Davy Pain, who collected the material. Compare Hibonite (q.v.).

Para-autunite. Author? H. Strunz, Min. Tab., 3rd edit., 1957, p. 254 (Para-Autunit). $Ca(UO_2)_2(PO_4)_2$, orthorhombic (pseudo-tetragonal). Meta-autunite-II of J. Beintema, 1938 [M.A. **7**–237]. Completely dehydrated in the para-uranite (Para-Uranit) series. In other mineral names (e.g. 18th List) the prefix para- is used in different senses.

Para-chrysotile. E. J. W. Whittaker and J. Zussman, 1955. Min. Soc. Notice, 1955, no. 91; Min. Mag., 1956, vol. 31, p. 116. A variety of chrysotile with X-ray fibre-axis 9·2 Å., distinct from clino- and ortho-chrysotile (20th List).

Paradamite. G. Switzer, 1956. Science (Amer. Assoc. Adv. Sci.), vol. 123, p. 1039. Zinc arsenate, Zn_2AsO_4OH, triclinic, dimorphous with adamite and isomorphous with tarbuttite. From Mexico. [M.A. **13**–380.]

Paramontroseite. H. T. Evans and M. E. Mrose, 1955, Amer. Min., vol. 40, p. 861. Vanadium dioxide V_2O_4, orthorhombic, as an oxidation product of montroseite, (V,Fe)O(OH) (19th List), from Paradox Valley, Colorado. [M.A. **13**–9.]

Phosphate-belovite. *See* Arsenate-belovite.

Plumbolimonite. G. H. Vertushkoe and Yu. A. Sokolov, Mém. Soc. Russ. Min., 1958, vol. 87, p. 96 (плумболимонит). PbO 15·38, Fe_2O_3 45·20, MnO 18·37, SiO_2 5·00, H_2O 12·51 %. With pyromorphite from Verkhne Ufaleya, Urals.

Polynite. E. A. Yarilova and E. I. Parfenova, 1957. Pochvovedenie (Pedology), 1957, no. 9, p. 37 (полынит). A montmorillonoid clay mineral in soils. Named after B. B. Polynov, Б. Б. Полынов (1877–1952). [M.A. **13**–580.]

Potash-scapolite. D. P. Serdyuchenko, 1955. Problems of geology of Asia, Acad. Sci. USSR, vol. 2, p. 742 (калиевые скаполиты). Scapolites containing up to 5·88 % K_2O from Yakutia. [M.A. **13**–186.]

Preobrazhenskite. Y. Y. Yarzhemsky, 1956. Doklady Acad. Sci. USSR, vol. 111, p. 1087 (преображенскит, preobrazhensquite). Magnesium borate, $3MgO.5B_2O_3.4{\cdot}5H_2O$, monoclinic (?). From the salt deposits at Inder, Kazakhstan. Named after Paul Ivanovich Preobrazhensky, Павл Иванович Преображенский (1874–1944), investigator of Russian salt deposits. Abstract in Bull. Soc. Franç. Min. Crist., 1957, vol. 80, p. 217 (preobrajenskite). [M.A. **13**–300.]

Priguinite. Error for Iriginite (q.v.).

Protodolomite. D. L. Graf and J. R. Goldsmith, 1955. Bull. Geol. Soc. Amer., vol. 66, p. 1566 (abstract); Journ. Geol. Chicago, 1956, vol. 64, p. 173. Imperfectly crystallized, artificial material approaching $CaCO_3.MgCO_3$ in composition. [M.A. **13**–88, 270.]

Przhevalskite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 8 (prjevalskite). Later publications, abstracts: Amer. Min., vol. 41, p. 816, vol. 43, p. 381; Mém. Soc. Russ. Min., 1958, vol. 87, p. 81 (пржевальскит, przhewalskite). $PbO.2UO_3.P_2O_5.4H_2O$. Named after Nikolai Mikhailovich Przhevalsky, H. M. Пржевальский (1839–88), Russian explorer in Central Asia.

Pseudolaueite. H. Strunz, 1956. Naturwissenschaften, vol. 43, p. 128. Orange-yellow monoclinic crystals from Hagendorf, Bavaria, with the same composition, $MnFe^{'''}_2(PO_4)_2(OH)_2.8H_2O$, as laueite (20th List). [M.A. **13**–210.]

Randomite. R. A. Van Nordstrand, W. P. Hettinger, and C. D. Keith, 1956. Nature, London, vol. 177, p. 714. Preliminary name for an artificial form of $Al(OH)_3$, with X-ray pattern distinct from those of associated gibbsite and bayerite. At first thought to have a random stacking structure. Later named bayerite-II.

Rhodesite. E. D. Mountain, 1956. Min. Soc. Notice, 1957, no. 97; Min. Mag., 1957, vol. 31, p. 607. J. A. Gard and H. F. W. Taylor, Min. Soc. Notice, 1956, no. 95, 1957, no. 97; Min. Mag., 1957, vol. 31, p. 611. A fibrous zeolitic mineral containing Al_2O_3 only 0·29 %, $4(Ca,Na_2,K_2)O.10SiO_2.7H_2O$, unit cell contents $(Ca,Na_2,K_2)_8Si_{16}O_{40}.11H_2O$, orthorhombic. Closely associated with mountainite (q.v.) from Bultfontein mine, Kimberley, South Africa. Named after Cecil John Rhodes (1853–1902) and Rhodes University, Grahamstown.

Santafeite. M. S. Sun and R. H. Weber, 1957. Bull. Geol. Soc. Amer., vol. 68, p. 1802 (abstract). Hydrous vanadate, $Na_2O.3MnO_2.6(Mn,Ca,Sr)O.3(V,As)_2O_5.8H_2O$, orthorhombic, black needles, on limestone from New Mexico. Named after the Santa Fe Railroad Company. [M.A. **13**–624.]

Sauconite. D. M. Roy and F. A. Mumpton, 1955. Bull. Geol. Soc. Amer., vol. 66, p. 1610 (abstract). Artificial $Zn(OH)_2$ as various polymorphs, the original sauconite (W. T. Roepper, 1875, 2nd List) being a montmorillonoid phase.

Sborgite. C. Cipriani, 1957. Atti (Rend.) Accad. Naz. Lincei, Cl. Sci. fis. mat. nat., ser. 8, vol. 22, p. 524. Hydrous sodium borate, $Na_2O.5B_2O_3.10H_2O$, triclinic. Deposit in steam pipes at the hot springs of Larderello, Tuscany. Named for Umberto Sborgi (1883–1955), professor of chemistry in the University of Milano. [Amer. Min. **43**–378.]

Schubnikowit. Geologie Zeits., East Berlin, 1955, vol. 4, p. 528. German transliteration of щубниковит, shubnikovite (20th List).

Serpentine-talc. H. Füchtbauer and H. Goldschmidt, 1956. Heidelberg. Beitr. Min. Petr., vol. 5, p. 195 ('Serpentintalk'). Between serpentine and talc in composition, $Mg_6Si_6O_{15}(OH)_6$, and physical characters. From silicification of dolomite in anhydrite bed of the Werra salt-deposits, Thuringia.

Severginite. G. P. Barsanov, 1951. Trudy Min. Mus. Acad. Sci. USSR, no. 3, p. 10 (севергинит). A variety of axinite containing MnO 14·79 %. Synonym of manganaxinite (5th List) and tinzenite (10th List, M.A. **12**–340). Named after Vasilii Mikhailovich Severgin, Василий Михайлович Севергин (1765–1826), Russian mineralogist. [M.A. **13**–353.]

Shorsuite. N. T. Vinnichenko, 1955. [Trudy Central Asiatic State Univ., no. 63, p. 19.] Abstracts in Mém. Soc. Russ. Min., 1956, vol. 85, p. 377 (шорсуит, shorsuite); Amer. Min., 1957, vol. 42, p. 441. White, fibrous, $(Fe,Mg)Al_2(SO_4)_4.19{\cdot}6H_2O$, between halotrichite and pickeringite. Named from the locality, Шор-Су, in Turkestan. [M.A. **13**–521.]

Simplotite. M. E. Thompson, C. H. Roach, and R. Meyrowitz, 1956. Science (Amer. Assoc. Adv. Sci.), vol. 123, p. 1078; Amer. Min., 1958, vol. 43, p. 16. Hydrous tetravanadite of calcium, $CaV_4O_9.5H_2O$, monoclinic, as dark-green plates and warty aggregates with U-V ores in crevices in sandstone from Peanut mine, Montrose Co., Colorado, and other localities in Colorado and Utah. Named after J. R. Simplot, former owner of the Peanut mine. [M.A. **13**–379.]

Smirnovite. V. G. Melkov and L. Ch. Pukhalsky 1957. [Minerals of the Urals, Moscow, 1957, p. 35.] Abstract in Mém. Soc. Russ. Min., 1958, vol. 87, p. 79 (смириовит, smirnovite = торутит, thorutite). $2[(Th,U,Ca)Ti_2O_6].H_2O$. Presumably named after S. S. Smirnov (see smirnovskite). Thorutite = thoria+rutile (?).

Smirnovskite. I. F. Grigoriev and E. I. Dolomanova, 1957. Mém. Soc. Russ. Min., vol. 86, p. 607 (смирновскит). Hydrous fluo-silico-phosphate of thorium, &c. $(Th,Ce,Ca...)OH.(P,Si,Al)(O,F,OH)_4$, Metamict. With cassiterite in quartz veins from Trans-Baikal. Named after academician Sergei Sergesich Smirnov, Сергей Сергесич Смирнов.

Smolyaninovite. L. K. Yakhontova, 1956. Doklady Acad. Sci. USSR, vol. 109, p. 849 (смольяниновит, smolianinovite). Hydrous arsenate, $2As_2O_5.(Fe,Al)_2O_3.4(Co,Ni,Mg,Ca)O.11H_2O$. Yellow, earthy oxidation product of Ni-Co ores from Bou-Azzer, Morocco. Named after Prof. N. A. Smolyaninov, Н. А. Смольянинов.

Smythite. R. C. Erd and H. T. Evans, 1956. Journ. Amer. Chem. Soc., vol. 78, p. 2017. R. C. Erd, H. T. Evans, and D. H. Richter, Amer. Min., 1957, vol. 42, p. 309. Iron sulphide, Fe_3S_4, rhombohedral; X-ray pattern similar to but distinct from pyrrhotine. Named after Prof. Charles Henry Smyth, Jr. (1866–1937), economic geologist. [M.A. **13**–380, 523.]

Soda-beryl. A. A. Beus and N. E. Zalashkova, 1936. Min. Sbornik Lvov Geol. Soc., no. 10, p. 273 (натриевый берилл). An alkali-beryl (12th List) containing up to 1·44 % Na_2O. [M.A. **13**–184.]

Sodium-nepheline. G. Donnay, 1957. Ann. Rep. Geophysical Lab., for 1956–57, p. 237 (sodium nepheline). Artificial $NaAlSiO_4$, as distinct from the usual nepheline $(Na,K)AlSiO_4$. Also, as deduced from X-ray data, natural at Monte Somma, Vesuvius.

Sogrenite. Author? [Russian textbooks, 1956, 1957.] Abstract in Amer. Min., 1958, vol. 43, p. 382. A black organo-uranium complex; perhaps identical with thucholite. Locality? etymology?

Starkeyite. O. R. Grawe, 1945. Missouri Geol. Surv., ser. 2, vol. 30, p. 209; Amer. Min., 1956, vol. 41, p. 662. First described from the

X-ray pattern as $FeSO_4.4H_2O$, and later shown to be $MgSO_4.4H_2O$ [leonardtite, 19th List, not to be confused with leonardite]. Named from the locality, Starkey mine, Madison Co., Missouri. [M.A. **13**–302.]

Stcherbakovite. Bull. Soc. Franç. Min. Crist., 1955, vol. 78, p. 352. French transliteration of щербаковит, shcherbakovite (20th List).

Stibioenargite. Author? H. Strunz, Min. Tab. 3rd edit., 1957, p. 97 (Stibioenargit). $Cu_3Sb.S_4$, orthorhombic. Artificial (?). Natural enargite $Cu_3(As,Sb)S_4$ contains up to 6 % Sb.

Stibio-tellurobismutite. I. G. Magakyan, 1956. [Doklady Acad. Sci. Armenian SSR, 1956, vol. 23, p. 215.] Abstract in Mém. Soc. Russ. Min., 1958, vol. 87, p. 76 (стибио-теллуровисмутит, stibio-tellurobismutite). $(Bi,Sb)_2Te_3$, rhombohedral, containing Sb 2·7 %. From Zodsk, Armenia.

Stilleite. P. Ramdohr, 1956. Geotektonisches Symposium zu Ehren von Hans Stille, Stuttgart, 1956, p. 481 (Stilleit). Abstract in Amer. Min., vol. 42, p. 484. Microscopical examination of an ore sample from Katanga showed a cubic mineral with X-ray pattern similar to that of artificial ZnSe. Named after Hans Stille (1876–), German geologist.

Stillwellite. J. McAndrew and T. R. Scott, 1955. Nature, London, vol. 176, p. 509. P. Gay, Min. Mag., 1957, vol. 31, p. 465. Boro-silicate of lanthanons, $(Ln,Ca)BSiO_5$, rhombohedral, in radioactive ore from Queensland. Named after Dr. Frank Leslie Stillwell, of Melbourne. [M.A. **13**–7.]

Strunzite. C. Frondel, 1957. Neues Jahrb. Min., Monatshefte, 1957, p. 222 (Strunzit). Monoclinic polymorph of laueite (20th List) and pseudo-laueite (q.v.), $MnFe_2'''(PO_4)_2(OH)_2.8H_2O$, as straw-yellow radiating fibres from alteration of triphyline, at Hagendorf, Bavaria, and 12 United States localities. Named after Prof. Hugo Strunz of Regensburg and Berlin.

Tetra-kalsilite. J. V. Smith and O. F. Tuttle, 1957. Amer. Journ. Sci., vol. 255, p. 286. T. G. Sahama and J. V. Smith, Amer. Min., vol. 42, p. 286. A form of kalsilite, $(K,Na)AlSiO_4$, with the hexagonal a-axis 20 Å., in the composition range Na_{20-30}. *See* Tri-kalsilite. [M.A. **13**–524.]

Thorutite. *See* Smirnovite.

Tialite, Tielite, Tieilite. Various renderings of the Japanese name, H. Strunz, Min. Tab., 3rd edit., 1957, p. 155 (Tialit). K. F. Chudoba, Hintze, Min., Erg.-Bd. II, p. 390 (Tielit). M.A. **11**–415; 19th List (Tieilite). Artificial aluminium titanate, Al_2TiO_5, isomorphous with pseudobrookite.

Titanmagnetite. A. F. Buddington, J. Fahey, and A. Vlisidis, 1955. Amer. Journ. Sci., vol. 253, p. 409. A titaniferous magnetite (titanomagnetite, P. Groth, 2nd List) containing TiO_2 in solid solution, as distinct from ilmenomagnetite (20th List) with exsolution ilmenite. *See* Mogensenite.

Titano-haematite. R. Chevallier, J. Bolfa, and S. Mathieu, 1955. Bull. Soc. Franç. Min. Crist., vol. 78, p. 310 (titano-hématites rhomboédriques). Variant of titanhaematite (17th List). *See* Ferri-ilmenite.

Tri-kalsilite. T. G. Sahama and J. V. Smith, 1957. Amer. Min., vol. 42, p. 286. A form of kalsilite, $(K,Na)AlSiO_4$, in parallel intergrowth with nepheline, $(Na,K)AlSiO_4$. The hexagonal a-axis 15·4 Å. is three times longer than that of kalsilite (a 5·15 Å.). *See* Tetra-kalsilite. [M.A. **13**–524.]

Trogtalite. P. Ramdohr and M. Schmitt, 1955. Neues Jahrb. Min., Monatshefte, no. 6, p. 139 (Trogtalit). Cobalt selenide, $CoSe_2$, cubic (pyrite group). Named from the locality, Trogtal, Harz. [M.A. **13**–5.]

Ufertite. Author? Guide to USSR exhibit at Conference on Atomic Energy, Geneva, 1955, p. 9 (ufertite). Later publications, abstracts: Amer. Min., 1957, vol. 42, p. 307, 1958, vol. 43, p. 378 (ufertite, uferite); Mém. Soc. Russ. Min., 1958, vol. 87, p. 78 (уфертит, ufertite). $20FeO.8Fe_2O_3.4$(rare-earths)$.74TiO_2$. Named from the composition U, Fe, Ti.

Ulvite. Author? H. Strunz, Min. Tab., 3rd edit., p. 138 (Ulvit). Fe_2TiO_4, cubic. Abbreviated form of ulvöspinel (18th List).

Uran-microlite. Author? H. Strunz, Min. Tab., 3rd edit., 1957, p. 147 (Uran-Mikrolith). Variety of microlite containing some uranium.

Uran-pyrochlore. Author? H. Strunz, Min. Tab., 3rd edit., 1957, p. 147 (Uran-Pyrochlor). Variety of pyrochlore containing some uranium.

Urhite. R. V. Getzeva, 1956. [Atomic energy, Moscow, no. 3, p. 135.] Abstracts in Mém. Soc. Russ. Min., 1957, vol. 86, p. 118 (уртит, urhyte); Amer. Min., 1957, vol. 42, p. 442 (urgite); Bull. Soc. Franç. Min. Crist., 1957, vol. 88, p. 538 (urgite). Hydrous oxide, $UO_3.2{\cdot}3$–$3{\cdot}1H_2O$, amorphous, yellow, in oxidized ore. Named from the composition. *See* Hydronasturan. [M.A. **13**–385 (urhyte).]

Usihite. V. G. Melkov and L. Ch. Pukhalsky, 1957. [Minerals of the Urals, Moscow, 1957, p. 67.] Abstract in Mém. Soc. Russ. Min., 1958, vol. 87, p. 84 ((усигит, usihyte). $R(UO_2)_2Si_2O_7.nH_2O$. Named from the composition.

Ustarasite. M. S. Sakharova, 1955. Trudy Min. Mus. Acad. Sci. USSR, no. 7, p. 116 (устарасит). Sulphosalt $PbS.3(Bi,Sb)_2S_3$, as grey prismatic crystals in bismuth ore from the Ustarasaisk deposit in western Tyan-shan, Siberia. Named from the locality. [M.A. **13**–164.]

Vanadium-garnet. S. T. Badalov, 1951. Mém. Soc. Russ. Min., vol. 80, p. 212 (ванадиевый гранат). Variety of grossular garnet containing V_2O_3 4·52 %.

Vanadium-tourmaline. S. T. Badalov, 1951. Mém. Soc. Russ. Min., vol. 80, p. 212 (ванадиевый турмалин). Variety of tourmaline containing V_2O_3 5·76 %.

Vesignieite. C. Guillemin, 1955. Compt. Rend. Acad. Sci. Paris, vol. 240, p. 2331 (vésigniéite); Bull. Soc. Franç. Min. Crist., 1956, vol. 79, p. 250. Copper-barium vanadate $Cu_3Ba(VO_4)_2(OH)_2$, with X-ray pattern similar to bayldonite $[Cu_3Pb(AsO_4)_2(OH)_2]$. Named after Colonel Jean Paul Louis Vésignié (1870–1954) of Paris, who supplied the material from his private collection. [M.A. **13**–6.]

Vinogradovite. E. I. Semenov, E. M. Bonshtedt-Kupletskaya, V. A. Moleva, and N. N. Sludskaya, 1956. Doklady Acad. Sci. USSR, vol. 109, p. 617 (виноградовит). Titano-silicate, $Na_5Ti_4AlSi_6O_{24}.3H_2O$, monoclinic (pseudo-orthorhombic), as white to colourless crystals and radial spherical aggregates in nepheline-syenite pegmatite from Kola. Named after Alexander Pavlovich Vinogradov, Александр Павлович Виноградов. [M.A. **13**–300.]

Wladimirit. E. I. Nefedov, Geologie, Zeits. Geol., East Berlin, 1955, vol. 4, p. 528. German transliteration of владимирит, vladimirite (20th List). [M.A. **13**–85.]

Wolkowit. E. I. Nefedov, Geologie, Zeits. Geol., East Berlin, 1955, vol. 4, p. 528. German transliteration of волковит, volkovite (20th List). [M.A. **13**–85.]

Wölsendorfite. J. Protas, 1957. Compt. Rend. Acad. Sci. Paris, vol. 244, p. 2942. $(Pb,Ca)O.2UO_3.2H_2O$, orthorhombic, as bright-red crusts in fluorite from Wölsendorf, Bavaria. Named from the locality. [M.A. **13**–520.]

Zirconolite. L. S. Borodin, I. I. Nazarenko, and T. L. Richter, 1956. Doklady Acad. Sci. USSR, vol. 110, p. 845 (цирконолит). A metamict mixed oxide $CaZrTi_2O_7$, containing also Nb, Fe, U, Ce, &c. In nepheline-pyroxenite [from Kola]. Similar to zirkelite [Min. Mag. **11**–86, **16**–309] from Brazil and Ceylon. [M.A. **13**–383.]

SYSTEMATIC CLASSIFICATION OF NEW MINERALS[1]

Sulphides, etc.

Hawleyite, CdS, VII.
Kadmoselite, CdSe, VI.
Ferroselite, $FeSe_2$, III.
Smythite, Fe_3S_4, V.
Freboldite, CoSe, VI.
Hastite, $CoSe_2$, III.
Trogtalite, $CoSe_2$, VII.
Bornhardtite, Co_3Se_4, VII.
Stilleite, ZnSe, VII.
Betekhtinite, $Cu_{10}PbS_4$, III.
Kësterite, (Cu,Sn,Zn)S.
Arsenopalladinite, Pd_3As, VI.

Sulphosalts

Isostannite, Cu_2FeSnS_4, VII.
Bonchevite, $PbBi_4S_7$, III.
Bursaite, $Pb_5Bi_4S_{11}$, II?
Ustarasite, $Pb(Bi,Sb)_6S_{10}$.
Gerstleyite, $Na_4As_2Sb_8S_{17}.6H_2O$, II?
Stibioenargite, Cu_3SbS_4, III.

Halides

Carobbiite, KF, VII.
Gearksite, $CaAl_3(F,OH)_{11}.H_2O$.

Oxides

Birnessite, δ-MnO_2.
Kurnakite, Mn_2O_3, IV, VII.
Cerianite, CeO_2, VII.
Paramontroseite, V_2O_4, III.
Zirconolite, $CaZrTi_2O_7$.
Hibonite, Al, Fe, Ca, Si, Ti, &c., VI.
Painite, $Al_{20}Ca_4BSiO_{37}.5$, VI.
Lodochnikite, $2(U,Th)O_2.3UO_3.14TiO_2$.
Ulvite, Fe_2TiO_4, VII.
Uferite, Fe, Ti, rare-earths.

Hydroxides

Sauconite, $Zn(OH)_2$.
Duttonite, $VO(OH)_2$, II.
Doloresite, $3V_2O_4.4H_2O$, II.
Häggite, $V_2O_2(OH)_3$, II.
Urhite, $UO_3.nH_2O$.
Hydronasturan, $UO_2.kUO_3.nH_2O$.
Wölsendorfite, $(Pb,Ca)O.2UO_3.2H_2O$, III.
Absite, $2UO_2.ThO_2.7TiO_2.5H_2O$.
Mauritzite, $(Fe,Al)_2O_3.2(Mg,Fe)O.5H_2O$.
Smirnovite, $(Th,U,Ca)Ti_2O_6.\frac{1}{2}H_2O$.

Carbonates

Kettnerite, $CaF(BiO)CO_3$, IV
Doverite, $YtFCO_3.CaCO_3$, V.
Chalconatronite, $Na_2Cu(CO_3)_2.3H_2O$, II.

Borates

Frolovite, $CaB_2O_4.3\frac{1}{2}H_2O$.
Calcioborite, $Ca_5B_8O_{17}$, II.
Sborgite, $Na_2O.5B_2O_3.10H_2O$, I.
Ezcurrite, $2Na_2O.5B_2O_3.7H_2O$.
Preobrazhenskite, $3MgO.5B_2O_3.4\frac{1}{2}H_2O$, II.
Lesserite, $Mg_2B_6O_{11}.15H_2O$, II.
Heidornite, $Na_2Ca_3Cl(SO_4)_2B_5O_8(OH)_2$, II.
Garrelsite, $(Ba,Ca,Mg)_4B_4(BO_4)_2(SiO_4)_2.2H_2O$, II.
Stillwellite (Ln,Ca)$BSiO_5$, V.
Alumoferroascharite, $(Mg,Fe)(B,Al)O_2.OH$.

Sulphates

Bonattite, $CuSO_4.3H_2O$, II.
Starkeyite, $MgSO_4.4H_2O$.
Galeite, $Na_2SO_4.Na(F,Cl)$, V.
Hornessite, Ni, Fe, hyd.
Shorsuite, $(Fe,Mg)Al_2(SO_4)_4.19\frac{1}{2}H_2O$.
Kašparite, $(Mg,Co)Al_3(SO_4)_5OH.28H_2O$.

[1] Only selected names from the preceding alphabetical list are here included. Following A. E. H. Tutton (Crystallography, 1911, 1922), the crystal systems are indicated as: I triclinic, II monoclinic, III orthorhombic, IV tetragonal, V trigonal, VI hexagonal, VII cubic.

Molybdates

Iriginite, $UO_3.2MoO_3.4H_2O$.
Moluranite, $UO_2.2UO_3.5MoO_3.12H_2O$.

Phosphates

Lithiophosphate, Li_3PO_4.
Neomesselite, $(Ca,Fe,Mn,Mg)_3(PO_4)_2.2H_2O$, I.
Kingite, $Al_2O_3.Al(OH)_3.P_2O_5.9H_2O$.
Metakingite, ditto, $4H_2O$.
Pseudolaueite, Strunzite } $MnFe'''_2(PO_4)_2(OH)_2.8H_2O$, II.
Lermontovite, $(U,Ca,\text{rare-earths})_3(PO_4)_4.6H_2O$.
Grayite, Th phosphate.
Przhevalskite, $Pb(UO_2)_2(PO_4)_2.4H_2O$.

Arsenates

Paradamite, $Zn_2AsO_4(OH)$, I.
Cornubite, $Cu_5(AsO_4)_2(OH)_4$.
β-Roselite, $Ca_2Co(AsO_4)_2.2H_2O$, I.
Smolyanskite, hyd. arsenate Fe, Al, Ni, Co, Mg, Ca.
Abernathyite, $K(UO_2)AsO_4.4H_2O$, IV.

Arsenite

Magnussonite, $(Mn,Mg,Cu)_5(AsO_3)_3(OH,Cl)$, VII.

Vanadates

Simplotite, $CaV_4O_9.5H_2O$, II.
Vesignieite, $Cu_3Ba(VO_4)_2(OH)_2$.
Nolanite, $3FeO.V_2O_3.3V_2O_4$, VI.
Santafeite, $Na_2O.3MnO_2.6(Mn,Ca,Sr)O.3(V,As)_2O_5.8H_2O$, III.
Francevillite, $(Ba,Pb)(UO_2)_2(VO_4)_2.5H_2O$, III.

Silicates

Kirschsteinite, $CaFeSiO_4$, III.
Sodium-nepheline, $NaAlSiO_4$, VI.
Bikitaite, $LiAlSi_2O_6.H_2O$, II.
Nekoite, $CaO.2SiO_2.2H_2O$, I.
Rhodesite, $4(Ca,Na,K)O.10SiO_2.7H_2O$, III.
Mountainite, $(Ca,Na,K)_{16}Si_{32}O_{80}.24H_2O$, II.
Combeite, $Na_4Ca_3Si_6O_{16}(OH,F)_2$, V.
Istisuite, $(Ca,Na)_7(Al,Si)_8(O,OH)_{24}$, II.
Götzenite $(Ca,Na,Al)_7(Si,Ti)_5O_{15}F_{3\cdot5}$, I.
Karpinskite, $(Ni,Mg)_2Si_2O_5(OH)_2$.
Karpinskyite, $Na_2(Be,Zn,Mg)Al_2Si_6O_{16}(OH)_2$, VI.
Kurumsakite, $8(Zn,Ni,Cu)O.4Al_2O_3.V_2O_5.5SiO_2.27H_2O$.
Jagoite, $(Pb,Ca)_3Fe'''Si_3O_{10}(Cl,OH)$, V.
Stillwellite, $(Ln,Ca)BSiO_5$, V.
Garrelsite, $(Ba,Ca,Mg)_4B_4(BO_4)_2(SiO_4)_2(OH)_2.2H_2O$, II.
Vinogradovite, $Na_5Ti_4AlSi_6O_{24}.3H_2O$, II.
Niocalite, $Ca_4NbSi_2O_{10}(OH,F)$, III.
Labuntzovite, $(K,Na,Ca)(Ti,Nb)Si_2(O,OH)_{7\cdot}\frac{1}{2}H_2O$, III.
Boltwoodite, $K_2(UO_2)_2(SiO_3)_2(OH)_2.5H_2O$, II?
Orlite, $3PbO.3UO_3.4SiO_2.6H_2O$.
Usihite, $R(UO_2)_2Si_2O_7.nH_2O$.
Nenadkevite, hyd. sil. U, Th, &c.
β-Uranophane, $Ca(UO_2)_2(SiO_3)_2(OH)_2.5H_2O$, II.

Hydrocarbons

Carpathite, $C_{33}H_{17}O$, II.
Minguzzite, $K_2Fe(C_2O_4).3H_2O$, II.
Agathocopalite.

SHORT COMMUNICATIONS

A crystal of sinhalite from Mogok, Burma.

On the 21st of May last, Mr. A. C. D. Pain submitted to this laboratory a number of unidentified rough stones from Mogok, Burma. Amongst these specimens was a crystal with well-developed though water-worn faces, showing a habit reminiscent of olivine but of brownish colour. An examination of its absorption spectrum and a density determination were sufficient to establish that the stone was sinhalite.

This had a double interest, since it was the first known occurrence of sinhalite in Mogok and also was the first well-developed crystal of the species to be discovered. Previously, water-worn pebbles had been recovered from the Ceylon gem gravels, though most known specimens were cut gemstones. In fact when it was first established as a new mineral by Claringbull and Hey[1] only cut stones were available.

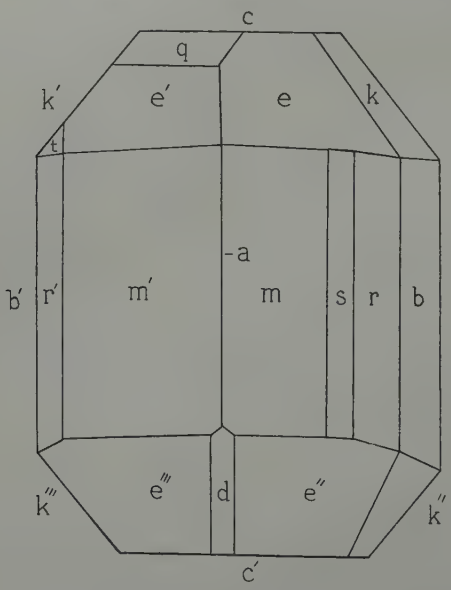

Fig. 1. Form development of a crystal of sinhalite from Mogok, Burma.

The specimen now briefly placed on record is an orthorhombic prismatic crystal, terminated at both ends with a basal pinacoid. It had grown on its back, which was not well developed. The crystal,

$8\frac{3}{4} \times 7 \times 5\frac{1}{2}$ mm., weighs 0·68 g, and a density value of 3·49 was obtained by hydrostatic weighing in ethylene dibromide. An idealized drawing, kindly made for the writer by Mr. T. H. Smith (fig. 1), shows the distribution of the different forms.

Owing to the roughened surface of the crystal, interfacial angles could only be determined approximately, using an eyepiece goniometer. But by calculation on the basis of the axial ratios previously measured by Claringbull and Hey, using X-ray methods, fair agreement was obtained with the measured values, and indices could be ascribed to the faces with reasonable certainty.

Forms shown were: Pinacoids, *b*{010}, *c*{001}, *a*{100}. Prisms, *m*{110}, *s*{120}, *r*{130}. Pyramids, *e*{111}, *q*{112}, *t*{132}. Domes, *d*{101}, *k*{021}. The angles, calculated and measured, were as follows (calculated angles in parentheses): *mm'* 47° (47° 20′), *me* 35° (34° 56′), *rb* 40° (40° 16′), *mq* 54° (54° 24′), *sb* 49° (48° 46′), *ck* 49° (48° 58′), *cd* 53° (52° 39′), *rt* 43° (42° 47′). The prism faces showed some of their original natural polish, and there was a suggestion of the *a* (100) face, by reflection.

It was not possible to measure the refractive indices of the specimen without damaging the crystal. The optic axial plane was parallel to (001), and the acute bisectrix was parallel to *b*. 2V was 55° approx., and the pleochroic colours were γ, pale greenish brown, β, pale brown, and α, brown; $\alpha > \beta > \gamma$.

Mr. Pain has kindly presented the crystal (B.M. 1958, 538) to the Mineral Department of the British Museum (Natural History).

Precious Stone Laboratory of the London Chamber of Commerce. C. J. Payne

[1] G. F. Claringbull and M. H. Hey, Min. Mag., 1952, vol. 29, p. 841.

Condurrite: a mixture and not domeykite.

An examination of the eight specimens labelled 'condurrite' in the British Museum collection, from Condurrow mine and from Wheal Druid, Cornwall, confirms the original observation by W. Phillips[1] that it is 'a mere mechanical deposit, arising from the natural decomposition of other ores which abounded in copper and arsenic'. Although condurrite has been taken as synonymous with domeykite,[2] Phillips stated specifically that he was giving the name to the black mineral and not to the metallic grains surrounded by it; our examination of X-ray powder patterns shows that these latter are either domeykite or β-domeykite,

whereas the black material is a compact and variable mixture of cuprite, melaconite, chalcocite, and one of the domeykite phases (though not all are present in any one sample). Both domeykite phases occur in specimens from the Condurrow mine, so it is not possible to distinguish between the two mines according to the domeykite phase present on any particular specimen. Our specimens tally with the descriptions given by Phillips and by J. Garby,[3] with the exception of a red earthy coating on the Wheal Druid specimens stated to be absent by the latter author, and there is no doubt in our records that all the specimens are authentic although not type material. Condurrite is thus established as a mixture, with cuprite or melaconite rather than domeykite as an essential constituent, and should no longer be regarded as synonymous with domeykite. I thank Miss E. E. Fejer for help in the interpretation of the powder photographs.

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[1] W. Phillips, Phil. Mag., 1827, vol. 2 (new ser.), p. 286 (with analysis by M. Faraday).

[2] E.g., Dana Syst. Min. 7th edn, vol. 1, p. 172.

[3] J. Garby, Trans. Roy. Geol. Soc. Cornwall, 1846, vol. 6, p. 194.

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